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1973

KEY DEER INVESTIGATIONS

FINAL REPORT

Period of Study: December 1967 - June 1973

Financial Contributors:

USDI Bureau Sport Fisheries & Wildlife
Southern Illinois University at Carbondale
National Geographic Society
North American Wildlife Foundation
National Wildlife Federation

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May 1, 1974

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During the past several years the Key deer, *Odocoileus virginianus clavium*, has increased in numbers following the low population level of the late 1940's and early 1950's. This response occurred after the deer were protected from intense hunting and disturbance to the population and its habitat (U.S. Fish & Wildlife Service Narrative Reports, 1939-1967; Dickson 1955). The increase in numbers, however, appeared to have been much slower than that characteristic of other white-tailed deer populations that have been afforded such protection and opportunity for increment. The reasons for this gradual increase, as well as questions regarding the physiology, subspecific status, and relationships of this deer to its unique island environment were of interest. The objectives of this study, which was undertaken in December of 1967 to clarify some of these aspects of the Key deer ecology, were as follows:

A. Primary

   1. Investigate movement and dispersal through the use of various marking devices including radio transmitters.

   2. Study social behavior and organization with emphasis on their effects on population dynamics.

   3. Examine the reproductive and survival potential.

B. Secondary

   1. Initiate nutritional studies.

   2. Establish a system to estimate population trends.

   3. Evaluate techniques to capture animals.

   4. Accumulate miscellaneous data on life history and ecology.

During January, 1968 through mid-September, 1968 and from December, 1968 through December, 1971, staff from the Cooperative Wildlife Research Laboratory, Southern Illinois University at Carbondale, were in continuous residence on Big Pine Key to collect data on the deer in its habitat. Subsequent periods of 2 weeks to 6 months were spent during 1972 and 1973, during which time specific emphasis was on capturing, marking, and monitoring pregnant does and newborn fawns, transplanting deer, and collecting vegetation samples. While field work was being conducted, personnel in residence at Southern Illinois University at Carbondale analyzed materials collected from mortalities and live deer which had been preserved and shipped as they were accumulated.

Personnel associated with the study were: Dr. W. D. Klimstra, principal investigator, Patricia Czapar, Allan L. Dooley, Todd Eberhardt, James W. Hardin, Bruce N. Jacobson, Katherine Jacobson, Jimmie R. McCain, Douglas E. Morthland, Patricia Morthland, James L. Rachuy, John W. Schulte, Nova J. Silvy, Virginia A. Terpening, and Thomas Trudeau.

The contributions of Mr. Jack C. Watson, Sr., Manager, Key Deer National Wildlife Refuge, to this research cannot be adequately emphasized. His efforts and dedication to insure support of the research and researchers are responsible in large measure for much contained in this report. Mr. Richard Bolt, Biological Technician, extended many extra efforts and an enthusiasm which greatly enhanced the research efforts. Immeasurable and invaluable contributions were made by Jack Watson, Jr., Terry Watson,

Mrs. Frankie Watson, Mrs. Val Silvy, many residents of Big Pine Key and adjacent keys, and the staff of the Cooperative Wildlife Research Laboratory of Southern Illinois University at Carbondale. Appreciation is also extended to Danny Bolt, Bill Schwicker, Robert Hawkins, John Roseberry, and William Klimstra, who assisted the project in various ways. Weather data collected and provided by Mr. Ralph Higgs of Big Pine Key was most helpful; and, Jim Buitt's efforts in construction and design of radio transmitters and collars were indispensable.

This study was funded by the U.S. Department of Interior Bureau of Sport Fisheries and Wildlife, National Geographic Society, North American Wildlife Foundation, National Wildlife Federation, and Southern Illinois University at Carbondale.

The extensiveness and intensiveness of this research have resulted in accumulation of materials and data that have not been analyzed or are as yet incomplete. It is planned to complete unfinished segments of the investigation and to pursue several avenues of research which have been suggested by the analysis of data gathered. Therefore, at subsequent times, theses and dissertations as well as publications will be finalized; copies will be supplied all collaborators who contributed to the initiation and progress of this study.

DEER CAPTURE

Techniques

Generally, Key deer proved difficult to capture as the more conventional methods either could not be used or were unproductive. During this study, of the numerous techniques employed with variable results, a 50x14-foot nylon net in conjunction with hand capture was most productive. The technique resulted in few mortalities and little or no injury to the deer. However, it could be used only where it was possible to corner the deer between dredged canals and then drive them into the net.

The use of nicotine in a syringe dart, shot with a capture gun or crossbow, was used and evaluated. This method provided the possibility of capturing deer in most habitats; but, the variability in the effect of the drug on different animals of the same age and/or sex and weight class resulted in unexpected mortalities. Variability in individual bottles of nicotine supplied by the manufacturer also seemed to play a role in this mortality. Although nicotine salicylate resulted in an occasional mortality, the quick action and characteristic excitement period produced enabled observers to keep an animal in sight until it "went down" or to locate the animal by sound during the excitement period. In areas where no other method is feasible, nicotine drugs may be justified even with the loss of an occasional deer due to the drug. This is especially true in outlying areas where numbers of Key deer are unknown and other methods cannot be used.

M99, because of the slow rate with which deer responded, the lack of an excitement stage, and the heavy cover conditions in most areas, was not an effective drug; but, it may have limited use under special conditions. Succinylcholine, prescribed by some, was not tried; but, efforts on our other deer studies showed it to be no better (if not less so) than nicotine.

Although deer were taken in nylon-net, metal-framed trail traps, the man hours and trap days required were excessive; and, this technique was not without mortality. Some animals escaped from traps either by breaking through the mesh or through mechanical failure of the door-drop mechanism. Use of a metal-framed net, drop trail trap proved ineffective; however, the use of a "suspension"-net trail trap was useful for capturing deer in areas where other techniques were impractical. This method consisted of a 40x40-foot square net placed in a major trail under a large tree. Pulleys and ropes were used in conjunction with a 150-lb weight which suspended the net trap when set. The trigger mechanism consisted of a #3 steel trap which, when sprung by a monofilament trip line, threw a sensitive friction-trigger mechanism that held the suspended 150-lb weight. Net suspension was accomplished by gravitational pull as the weight fell. The ideal situation was to have the deer suspended above the ground, thereby eliminating any struggle due to ground contact and a surface for leverage. Suspension trail traps were checked morning and evening to avoid long exposure of animals. Although trail traps permitted capture of deer in remote areas, the absence or distribution of large trees greatly restricted their use.

Trail trapping generally exhibited problems because Key deer were "spooky" of such devices; and, after experience with such traps they regularly discontinued use of given, well-used trails. This was an advantage in some respects as unwanted recaptures were eliminated. However, the trail traps could not be selective, and their operation was demanding both in time and regular scheduling. Difficulty was also experienced with protection of these traps; one net suspension trap was mistaken as poaching and destroyed, and a second trap was stolen.

Hand-capture of animals proved a very effective method. Young-of-the-year seemed especially susceptible to hand-capture when they began traveling alone and when found along roadways at night where they could be confused with lights and the vehicle motor. Fawns less than 2 weeks old were readily hand-captured during the day if they could be located. Location of radio-tagged does following birth of fawns resulted in numerous fawns being captured. Searching areas during the peak fawning season (April-June) also led to captures.

In general, techniques used were sufficient to capture animals for life history, mobility, and dispersal studies. Difficulties arose when individual deer needed to be recaptured for collar and/or radio replacement, and for capturing individuals in areas where desirable methods proved unsuccessful. Such difficulties not only interrupted continued data collection on individual animals but made it more difficult to establish population estimates. Problems in capturing animals on outlying keys were not resolved.

A multitude of baits were tried in previous years by Refuge personnel without success. During this study cultivated sapodilla (Sapota achras) fruits were experimented with as bait along regular travel lanes. Deer and raccoons utilized the bait quite readily; however, the volume needed for pre-baiting soon exhausted the supply. Snowberry (Chiococca alba) was effective as bait for the suspension trail traps. Leaves on this plant stayed "fresh" for 2 or 3 days and were even eaten by deer when dry.

Results

During this study a total of 364 deer were captured, including 131 recaptures. Of these, 227 (88 adult does, 45 adult males, 27 yearling males, 20 yearling females, 34 male fawns, and 13 female fawns) were restrained in a 50-foot net and captured by hand; and, 21 animals (9 adult does, 7 adult males, 1 yearling female, 1 male fawn, and 3 female fawns) were captured after they had jumped into dredged waterways. Eighty-eight animals (10 adult males, 6 adult does, 3 yearling females, 49 male fawns, and 20 female fawns) were captured by hand; one yearling female and one male fawn were captured by hand after being hit by an automobile. Fourteen animals (6 adult does, 3 adult males, 3 yearling females, 1 yearling male, and 1 male fawn) were taken with the use of nicotine salicylate and capture gun; three animals (1 adult male, 1 adult doe, and 1 yearling female) were taken with nicotine and the crossbow. Six animals were captured in trail traps; three (1 adult male and 2 male fawns) in a net trail trap and three (2 adult females and yearling male) in suspension trail traps. Two animals, hand-caught while swimming between islands,

included an adult doe while swimming between Big Pine and Porpoise Keys and a male fawn while swimming between Water and Big Torch Keys. One yearling male was found entrapped within a vegetation exclosure.

Of the animals subjected to the various capture techniques or situations, six (3 yearling females, 1 adult female, 1 yearling male, and 1 male fawn) died from use of nicotine salicylate; one adult male died from self-inflicted wounds in a net trail trap; and 3 animals (1 adult male, 1 yearling male, and 1 male fawn), after running into the trapping vehicle, were paralyzed and had to be sacrificed. One yearling male, found in a vegetation exclosure, was sacrificed due to a broken jaw and one adult doe recaptured by hand was sacrificed due to blindness in both eyes. Three animals (1 adult male, 1 adult doe, and 1 male fawn) died from injuries resulting from use of the 50-foot net. The death of two other adult males may have also resulted from net injuries.

Seventy-eight percent of the captured animals were trapped between 2200 and 0659 hours. The period when the greatest number of deer were trapped was between 2300 and 2359 hours, when 65 animals were taken. The second greatest period of success was between 0500 and 0559 hours, when 55 animals were taken. The period during which the least number of animals were captured was between 1300 and 1359 hours, when no animals were taken, followed by the period between 1900 and 1959 hours, when only one animal was trapped. Of the 81 animals trapped between 0700 and 2159 hours, 59 or about 73% were fawns.

Of the 232 deer captured for the first time, 207 were taken within Refuge lands or in subdivisions surrounded by Refuge lands.

Seven of the 25 animals not caught on Refuge lands were taken on No Name Key; all other animals were captured on Big Pine Key. Port Pine Heights Subdivision supplied the most animals (100 initial captures) followed by Eden Pines (43 animals) and Koehn's (39 animals) subdivisions. Of the 131 animals recaptured, only 3 were taken off Refuge lands. Eighty-eight animals were recaptured in Port Pine Heights with 26 and 8 being retaken in Eden Pines and Koehn's subdivisions, respectively.

DEER MONITORING

Marking

Various methods of marking deer for subsequent identification were employed. Early in the project, deer were marked with 10x1-inch nylon colored ear streamers held in place by a 1½-inch square white plastic cattle ear tag. Ear tags were self-locking and numbered consecutively with contrasting black numbers. The tags consisted of male and female parts and were affixed through a hole in the ear made with a hole punch. A few animals early in the study also had small (1x¼-inch) red painted self-locking, consecutively numbered aluminum ear tags applied. In 1969, the above tags were replaced with 1¼-inch round, self-locking, natural colored aluminum, black paint-filled, consecutively numbered tags. These tags were used throughout the rest of the study.

Beginning in 1969, all deer received in addition to the metal tag a number tattoo matching the one on the metal tag. The tattoo was applied to the inner portion of an ear with dies containing 3/8-inch numbers or letters. A revolving-head tattoo with ear release that held four dies allowed for sufficient number combinations to individually mark all deer. Three digits were used to individually mark all deer except very small fawns, which were marked with a single letter. When later recaptured these were number-tattooed as all others.

Originally, deer were collar-marked in one of two ways. If a radio were to be attached to the collar, it was made of a leather-strap dog collar with radio components riveted and taped to the

collar. Animals without radios had collars made of 5-inch-wide plastic-coated nylon that were riveted around the neck. To allow for neck expansion of fawns and males during periods of growth or the rut, strips of 1-inch-wide nylon elastic were utilized in the nylon collars. Slots cut into the leather collars allowed for buckle slippage and neck expansion of radioed collars.

A new collar design was developed and employed in December of 1968 which was made of Boltaron (a thermal plastic) and shaped to fit the contours of the neck of each age and sex class. The basic design was "U"-shaped, the open end at the top of the animal's neck when fitted. In the case of does, the open ends of the "U" were riveted (brass rivets). Where growth and expansion of the neck had to be accommodated in the case of bucks and fawns, elastic straps were placed on the inside of the collar and attached by rivets at the bottom of the "U". These straps passed through brass rod guides embedded in the open ends ("U") of the plastic collar, permitting the expansion and contraction. However, with time the weight of the collar, with or without a radio at the base, resulted in extension of the elastic and hence sagging of the collar. This was resolved by designing a "C"-shaped collar with ends overlapping at the side of the neck and elastic bands to resist expansion to the point of completely opening the "C".

Boltaron collars were made of two different thicknesses (.090 inch and .125 inch) and of two colors (black and white). Various colors of Scotch-lite reflective tape were attached to all Boltaron collars to form numbers, letters, or symbols which made for ready

identification both day and night (with artificial light) of individual animals. Radios were mounted on and antennas embedded in the Boltaron collar for radio-marking animals. Fawns were marked with a 1x1½-inch Boltaron strip riveted to a piece of nylon elastic. The nylon elastic was riveted together after it was placed around the animal's neck. Radios with small whip antennas mounted to the Boltaron strip allowed for radio-marking.

Two styles of sheep bells, utilized early in the study, were attached to the animals by means of nylon elastic straps with ends riveted together after being placed around the deer's neck.

Results

During this study 221 deer were collar-marked; one animal was marked only with an ear-tag and streamer and a second animal received only an ear-tattoo. Six animals were fitted with the plastic-coated nylon collars, 10 carried the leather radioed collars, and 17 bucks wore "U"-styled Boltaron collars. Of 33 fawns collar-marked, all but four had radios mounted on the collars. All other deer were fitted with Boltaron doe-styled ("U") or "C"-styled buck collars. During this study, 223 deer were marked for the first time and released; 50 were recaptured once, 8 twice, 10 three times, 4 four times, 2 five times, and 1 adult buck six times. These recapture data and field observations provided the opportunity to evaluate marking techniques.

There was extensive loss of ear tags and streamers, largely due to tissue damage and deterioration due to the tags. This resulted in these markers eventually dropping out of a notch or hole in the

ear. No streamer endured for as long as 2 years. The longest a white plastic ear tag stayed on was about 3 years; but, most of these were very short-lived. One small red metal tag was still on after almost 5 years. The aluminum metal ear tag, used later in the study, was still on after 3½ years.

Recoveries from deer that have been number-tattoed for over 3 years showed that such identification held up surprisingly well. These ear tattoos solved some problems of permanently marking animals.

The leather radio-collar and plastic-coated nylon collar were unacceptable. Due to the salt water and air, the leather collars quickly rotted. The longest period that a leather collar was known to last was approximately 5 months. The plastic-coated nylon collar fared only slightly better with a maximum life of 9 months.

The change from plastic-coated nylon and leather to Boltaron collars contributed a much higher degree of permanency, especially for adult females. The necessity of expansion collars for males and fawns presented difficulties. Problems developed with the "U"-shaped Boltaron collars that were used, especially when radios were attached. The rubber in the nylon elastic quickly stretched due to the constant weight of the transmitter and/or collar. Once the elastic failed, the collar would hang below the animal's neck and thereby allow the animal's foot to become entangled in the collar; the collar was then usually lost. Such collars without radios gave better service as there was less weight; but at best, these were not completely acceptable. The longest a "U"-shaped buck collar with radio lasted was about 10 months; without an attached radio it was

11 months. An attempt was made to recapture animals with such problem collars.

Adult doe Boltaron collars held up well with very few being lost. The lighter weight (.090-inch) Boltaron used on most doe collars may have been responsible for those that were lost. There were few known losses of doe collars constructed of the heavy-weight Boltaron; some of these have been on for almost 4½ years. Three doe collars mounted with radios were still being carried, though not transmitting, after a period of over 3 years. There has been some difficulty with corrosion of copper rivets (later found to be only copper-coated); these were later replaced with brass rivets, which stopped the corrosion problem.

The "C"-designed buck and fawn collar greatly reduced losses experienced with "U"-styled collars, which usually fell off after 6 months. Most collars served well on adult bucks until the rut, when the ferocity of the conflict between adult bucks resulted in collars being ripped from the animals' necks. Collars with radios attached seemed more easily lost than those without radios. Two years was the maximum period that radio-collars lasted on an adult buck; without a radio, one was carried for 2½ years.

Collar loss resulted for a variety of reasons. Few collars on breeding, adult males made it through the rut period because of the intense fighting. Corrosion of the copper-coated rivets may have resulted in a few losses. Occasionally split rivets straightened and separated, or the elastic frayed, allowing a collar to drop and be lost. A loose-fitting collar permitted catching on branches and hence collar loss. Also, a loose collar resulted in wear and

abrasion on the neck. In one instance a tight collar cut into the animal's neck and resulted in infection and blindness.

The collars for new fawns held up surprisingly well. It had been feared that, due to the small size of the collar (2-inch-diameter), if the collar could not be replaced within a short period there would be injury. However, two animals were carrying these collars 2 years after attachment and with no sign of problems. In both cases, the elastic had broken down and the collar had stretched adequately.

Sheep bells, placed on five animals (one adult doe, one yearling doe, one male fawn, and two female fawns), were extremely useful as they made it much easier to locate an animal without it being aware of the investigator. However, complaints by residents of subdivisions about bells tinkling at all hours of the night required their removal and discontinuation of their use. One animal carried a bell for nearly 1 year prior to removal; two deer were roadkilled while still wearing bells; and, two deer lost bells after nearly 1 year.

The Scotch-lite reflective tape was never known to have been lost from a collar. There was some problem in finding enough distinguishable numbers, letters, and symbols to individually mark a large number of deer. The use of a 3-inch-wide collar limited the amount of space for numbers that were large enough to be readily seen. Collars large enough for two numbers were found to cause neck abrasions and inhibited sideward neck movement. The use of different colored reflective tape (white, red, blue, yellow, green) on black and white Boltaron collars helped solve some of the problem. Color

combinations of reflective tape and colored Boltaron were difficult to distinguish at night under artificial light, and thereby could not be used. The white reflective tape on a black collar was the most readily distinguished combination. Yellow on black, red on white, blue on white, and green on white were useful in the order listed.

The Boltaron collars proved effective as a marking technique, as well as for mounting radio transmitters. It is believed that such collars can provide a permanent identification for females. Tattoos, although not recognizable at a distance, should provide the most permanent marking for all animals.

Telemetry

The receiving system consisted of two 12-channel AVM receivers and two Hy-Gain Model 23 two-meter, hand-held and truck-mounted antennas as designed by AVM Instrument Company, Champaign, Illinois. The transmitters were built by W. H. Cochran, AVM Instrument Company, and James Buitt, former research assistant, Cooperative Wildlife Research Laboratory, Southern Illinois University at Carbondale.

Transmitters for adult animals were designed for a theoretical operation of 300-600 days and a working range of a minimum of 1 mile. Three-stage transmitters employed later in the study were designed for greater field life and success. Adult radio packages weighed up to 454g; the weight depended on the size and number of batteries used. Three-stage transmitters required additional batteries for operation and thereby weighed more than two-stage radios. Early in the study 11-inch, stainless steel whip antennas were used with

radio packs; however, later antennas were made of copper wire and embedded in the Boltaron collars. An experimental radio equipped with rechargeable batteries powered by solar cells was also tested.

Newborn fawns were radio-marked with single-stage "quail" type radios mounted on 1x1½-inch pieces of Boltaron with a .030-inch-diameter, 8-inch steel cable, whip antenna. These units, which weighed about 17g, were attached by elastic bands around the neck. Theoretical life for these radios was 30 days if one hearing-aid battery was used as a power source. Working range for these transmitters was approximately 1/8 mile. As fawns grew, larger battery packs were added to the transmitter package to obtain longer life. At about 9 months of age, adult collars were carried without adverse effects.

Attempts were made to replace all radios before battery life was exhausted. In addition, radios on adult bucks were replaced prior to and following the rut because this was the most convenient time to recapture, coinciding with their period of greatest activity and, hence, accessibility. All lost radios were replaced as soon as animals could be recaptured.

An effort was made to have sufficient numbers of each sex and age group radio-tagged for movement, range, and dispersal studies. During certain periods of the study, efforts were made to concentrate on radioing selected sex and/or age groups to obtain specific data. Numerous adult does were radio-tagged prior to fawning to obtain new fawns for radio-tagging and fecundity data. Efforts were made to tag as many newborn fawns as possible to obtain data on social relationships and fawn movement and ranges.

Results

Most of the telemetry equipment performed satisfactorily during this study. A total of 187 radios were placed on 119 deer; of these, 98 were recovered, 38 were still being carried by animals when field observations were terminated, and 51 were either lost or were on animals not seen within the last 6 months of field study. The sex and age of animals when first radio-tagged included: 20 adult males, 38 adult does, 7 yearling males, 6 yearling females, 31 male fawns, and 17 female fawns.

Average field life of the radios was not established, as attempts were made to replace radios before they were expected to cease to function. After transmitting for 8-9 months, attempts were made to recover radios at any opportunity. However, one radio operated continuously in the field for 20 months. Two radios placed on adult animals in December, 1968, subsequently lost due to collar design, continued to transmit for nearly 2 years. Field life for fawn radios having only a single hearing-aid battery was approximately 30 days. With more and larger batteries, fawn radios operated for longer periods.

The stainless steel whip antennas were not suitable due to corrosion and breakage. Embedding antennas in the Boltaron collar virtually eliminated this problem; this technique was subsequently used on all but fawn collars. However, embedding the antenna reduced the range experienced with the whip by 25% to 30%. Two-stage transmitters had a working range from ½ to 1 mile; whereas, three-stage radios could be located up to 2 miles using a truck-mounted or hand-held receiving antenna.

Day-old fawns showed no adverse effects due to radios powered by a single hearing-aid battery. These radios did lack range and were short-lived, making it necessary to recapture these animals and replace these radios at frequent intervals. Through continuous radio-tracking, at around 25-day frequencies, fawns with operating radios were recaptured and equipped with a new power supply. These animals could be rather readily caught at night when bedded. If radios ceased to operate prior to this period, recapture was delayed.

Damage to the power supply by moisture and salt, along with some component failure, reduced transmitter life so that the theoretical life was rarely realized. This meant frequent radio replacements. One adult buck carried seven different radios during this study. A yearling doe, which was much easier on radios than adult bucks, was equipped with six different radios. Field tests of rechargeable batteries powered by solar cells suggested that during periods of darkness there was a back drain on the batteries, discharging them. Thereafter the radio worked only when solar cells were in direct sunlight. Also, the heavy cover of the Key deer habitat probably negates successful use of currently available radios powered by solar cells.

The number of deer bearing functional radio transmitters reached a high of 43 animals during May, 1971. It was possible to have adequate numbers of deer bearing functional transmitters during most of the period of study to adequately investigate movement, range, and dispersal. The major difficulty was in keeping adequate adult males with functional radios through the period of rut.

HERD DYNAMICS AND POPULATIONS

Big Pine Key Population

A once-weekly (Thursday) road census, conducted over a predetermined route within the Refuge on Big Pine Key (Figure 1), was begun in June, 1968. Two persons, each spotlighting from opposite sides of an automobile, carried out the census through June, 1972. The 10-mile census route was begun at 2230 hours and completed in 1 hour, depending on numbers of deer observed and attempts to capture deer. All deer observed were recorded according to age and sex classes; those which could not be so recognized were noted as unidentified. Marked animals were recorded; and, in most instances, these were specifically identified. Because all variables were held constant, sex and age ratios were available for an unbiased reflection of deer population trends and habitat use patterns.

During January-December, 1971, a 44-mile road census covering all major roads on Big Pine Key (Figure 2) was established and run on alternate Wednesdays beginning 1 hour before sunrise and then run again, commencing 1 hour before sunset. These censuses were conducted similarly to the standard 10-mile census with the intention of establishing an estimate of the deer population for all of Big Pine Key.

Ten 1/10-mile pellet transects were established on Refuge land during 18-20 February 1969 in five major vegetation types. All pellets dropped prior to establishment of the transects were removed. These transects were run at 3-month intervals for a period of 6 months. It was hoped that vegetation-use trends, as well as yearly overall deer-use trends might be established.

Islands other than Big Pine Key were visited periodically to determine, by observation of animals or sign, an estimate of the number of deer present. No Name Key, however, was visited almost daily during this study. The suitability for deer habitation was also determined at this time.

All mortalities were examined to determine if the animals had been marked. An adaptation of the Schumacher-Eschmeyer estimate procedure was applied to mortality data in estimating deer numbers. The number of deer killed per year was obtained to determine if it would reflect population trends.

Results

When applying the Schumacher-Eschmeyer estimate procedure to provide population estimates, knowing the number of marked animals remaining in the population at any given point in time was essential. Early in the study all marked animals not seen prior to 6 months of the point in time in making an estimate were arbitrarily eliminated from further consideration. In a few cases, however, some of these eliminated animals subsequently turned up, still being marked. In these cases census data were recalculated using the date that an animal was last seen with a collar during the study. Although the routine road-run censuses were discontinued in June, 1972, general observations continued until September, 1973; this permitted additional information on the presence of marked animals in the population through June, 1972. This approach to data analysis seemed to yield more objectivity and less bias; however, such accumulated data altered some of the analyses previously provided in quarterly and annual reports.

In establishing population estimates, fawns were not added to the data (even if seen) until October of the year of birth. This was done because few fawns were active at night prior to the last quarter of the year. Because of this, population estimates would exhibit an increase starting with the October-December period of each year. To accommodate this system of population analysis, annual estimates were begun with the October data. Hence, such analyses were instigated with the October census data of 1968.

In general, quarterly population estimates, as based on the 10-mile census data, showed an increase in the deer population from 42 animals for the July-September period of 1969 to a high of 156 animals during the January-March period of 1971 (Table 1). The estimate for the October-December period of 1968 seems inappropriate to emphasize because of the small number of marked deer in the population and the high standard error recorded. After January-March of 1971 the population seemed to have decreased to 96 animals, as determined for the April-June period of 1972. However, the decline throughout 1971 and 1972 was not believed a true population recession, as following a drought in 1970-1971 animals may have returned to outlying keys, resulting in lowered population estimates. Estimates prior to the drought in April-June, 1970, and those following the drought in April-June, 1972, yielded populations of 98 and 96 deer, respectively. This seemed to indicate a stable population on the Refuge area of Big Pine Key. The decline in population estimates noted in all years during the July-September period was expected, as the fawn crop was not incorporated in the analyses until the

October-December period. Mortality would result in gradual reduction (theoretically, at least) in the total population following the period when fawns were first added to the population.

Combining quarterly census data to determine annual population estimates for the area censused yielded a total of 61 deer in 1969 (October, 1968-September, 1969), 83 in 1970, 120 in 1971, and 106 in 1972 (October, 1971-June, 1972).

The 1970-1971 drought may have resulted in deer movement from outlying keys to Big Pine. Also, the "normal" population on Big Pine may have been more active in and around a large water area along the census route. Both factors were believed to have contributed to the increase in number of deer recorded. It was of interest that an increase was evident, also, when the number of deer seen per mile along the 10-mile census route was examined for the last 4 years. During 1969 and 1970 an average of 0.65 deer per mile were observed, whereas during 1971 and 1972 the average number of deer seen per mile was 1.11 and 1.14 deer, respectively. This indicated a population increase during the last 2 years over the previous 2 years. The full effects of drought periods on deer utilization of given keys is not yet clearly established. However, because of the annual rainfall pattern in the lower keys, many outlying keys can be of temporary use only. The impact of this "shuffling" on the overall population of Key deer must in some way be accommodated. Appreciate, too, the "normal" occurrence is during the latter part of the breeding season and when most does are pregnant. The impact of increased interaction on reproduction at this time should not be underestimated.

The number of deer seen per mile along the 10-mile census route through the Refuge was correlated with the Schumacher-Eschmeyer population estimate to determine if the number of deer seen per mile represented deer population trends. The Schumacher-Eschmeyer population estimate and the number of deer seen per mile should both be independent indications of the herd increase or decrease during a given year. When population estimates were made, only the ratio of marked to unmarked animals was considered; therefore, the number of deer seen per mile was independent of this estimate, and likewise the ratio of marked versus unmarked animals seen was independent of the number of deer seen per mile.

During future years when only Refuge personnel are available, it will be impractical for them to devote the time and energy necessary to keep sufficient numbers of deer marked for yearly population estimates. Because of the close correlation between the number of deer seen per mile and population estimates, increases or decreases in the herd can be monitored with the use of trend data. However, Refuge personnel must be aware that certain months of the year were better for sighting deer along the census route than others (Table 2). When comparing the 4 years of data for this study, deer were more likely to be seen along the census route during December-May than during June-November. Therefore, only the data for the same months of the years should be compared when determining deer population trends.

A close look at the 10-mile road census data for the last 4 years indicated that Key deer populations on Big Pine Key may be approaching stability (Table 3). These data showed a large increase in the

number of deer sighted along the census route between the second and third years of the study. Population estimates indicated that this was due to a population increase. During the third and fourth years of the study the population appeared to level off. This in itself may not be significant; but, the percent of bucks, does, and fawns seen during these years indicates population stabilization. During the past 4 years the percent of fawns seen decreased, whereas the percent of adult bucks and adult does increased. It is common knowledge that when a population exhibits an increasing segment of adult animals, stabilization is in progress. We are of the opinion that the Key deer population on Big Pine Key has, or will have in the near future, reached a peak level. With the continued commercial land development of this Key, the Key deer population can only decrease.

A statistical analysis of the sunrise-sunset data for January, 1971 through December, 1971 indicated that there was no significant difference between the number of deer seen on the sunrise census (341 deer seen) and the sunset census (343 deer seen). However, the proportion of marked to unmarked deer seen for the sunrise census was significantly less ($P \leq .05$) than that for the sunset census.

Behavior of radio-tagged animals indicated that at sunset certain animals moved into open areas to feed. Because most of these animals were marked due to the opportunity to capture, such animals were more readily seen; this led to a bias for the sunset census. During the sunrise census animals seen were rarely in open, developed areas; they were usually crossing roads as they moved to bedding and loafing areas. Therefore, the probability of seeing unmarked animals was just as great as seeing marked animals. For this reason the sunrise

census was considered the best census for population estimates. Application of the Schumacher-Eschmeyer technique revealed a population of 177 animals for Big Pine Key when both sunrise and sunset data were utilized. Individually, the sunrise census yielded a total of 213 animals, in contrast to 165 animals for the sunset census during January, 1971 through December, 1971.

The ten 1/10-mile pellet transects that were established on Refuge land during February, 1969 were run during May and August of 1969. Seventeen pellet groups were found on two transects in May and only one transect yielded six pellet groups in August. A hammock vegetation-type transect located in Watson Hammock produced all except one pellet group found. This would appear to be a heavy deer-use area; however, 20 of these 21 groups were found along the east half of this transect which had been burned 12 February 1969. This indicated the attraction of burned areas to deer after the appearance of new grasses following a burn. Because of apparent and anticipated problems in the application of this technique, the use of the transects for determining population levels or trends was discontinued. Thick vegetation, uneven deer use, periodic shifts in centers of deer activity, porosity of the oolitic limestone, deer use of tidal zones, as well as a variety of behavioral characteristics of the Key deer seemed to eliminate this as a useful technique, at least on Big Pine Key.

An application of the Schumacher-Eschmeyer estimate procedure to the 251 accidental deer mortalities on Big Pine Key yielded highly variable and unrealistic results. The use of mortality data has the

advantage that loss of collars does not affect the results, as animals are considered marked if they are marked in any way. Only the close inspection of a dead animal makes this method effective. However, there was a disadvantage as all marked animals were considered alive unless found dead. If marked animals had left the key in any way (dispersal or illegal hunting) or had died and not been located, they would still be included as part of the marked animal pool where, in reality, they were not. This would tend to bias the method by overestimating the population.

The fact that bucks were more likely than does to be roadkilled also added bias to this procedure. Female animals tended to stay in smaller home ranges than bucks, and were less likely to disperse. The fact that more adult and yearling females were marked during this study than males of these age classes (Table 4), and were marked mostly in the Refuge area away from the Overseas Highway, also added to this bias. The probability of a marked doe being killed in the high mortality area of the Overseas Highway was much less than it was for the unmarked buck, which tended to disperse to that area. These facts also tended to bias any mortality estimate by overestimating the population. Hence, roadkill data has limited use in population estimates.

The use of roadkill data to determine population trends may also be somewhat impractical. Data from 1968 through 30 June 1973 (Table 5) indicated that total roadkills on Big Pine Key follow a cyclic pattern, being high one year followed by a low the next. This cycle may have resulted from a delay in dispersing animals

repopulating the area around the Overseas Highway following a year of heavy losses. Also, other factors may have been involved that are yet unknown. Periods of drought may have a great affect on the number of animals roadkilled, as well as the segment of road in which they were killed. The data on roadkills during the drought of 1970-1971 showed almost 40% of the animals roadkilled on State Route 940; whereas, prior to and following the drought, animals killed on this road ranged from only 19% to 26.1%. This suggested that animals may have moved away (north) from the Overseas Highway into areas with a better water supply. The possibilities of animals returning to Big Pine during drought years would also affect roadkill trends. An even greater bias to the use of roadkill data to determine population trends would be the differing amount of automobile traffic using Big Pine Key from year to year.

Populations of Other Keys

To determine deer use and activity on keys other than Big Pine, observational trips were periodically made to outlying keys. Thirteen trips were made to Water Key, 12 to Big Johnson Key, 11 to Big Torch Key, 10 to Cudjoe and Little Pine Keys, 9 to Porpoise Key, 8 to Mayo Key, 7 to Howe Key, 6 to Big Munson Key, 5 to Middle Torch Key, 4 to Sugarloaf, Annette, and the Newfound Harbor Keys, 3 to Little Torch, Content, Raccoon, and Summerland Keys, 2 to Big and Little Spanish, Grassy, Horseshoe, Ramrod, Loggerhead, and Little Johnson Keys and an unnamed island southeast of Ramrod Key. Cutoe, East and West Bahia Honda, Wahoo, Crawl, Toptree Hammock, and Big Knockemdown Keys were each visited once. No Name Key was visited

almost daily. Estimation of deer populations on these is at best an educated guess based upon deer seen and evidence of deer use and activity.

No Name Key. The population of deer on No Name Key was probably surpassed only by Big Pine Key. Deer were readily seen on this Key, which is privately owned and was recently subjected to a very rapid rate of development. Approximately 1/6 of the Key was cleared during this study and subdivisions with dredged canals were prepared. The fate of its deer population will be determined in the next few years as development continues. Adequate acceptable fresh water was available during the entire drought of 1970-1971. Annual reproduction was evidenced by numerous observations of fawns. No Name contains all major vegetation types and offers considerable habitat variety for deer support.

During this study five deer were trapped and marked on No Name. In addition, three adult bucks were transplanted to the Key; one returned to Big Pine Key. Ten deer (4 adult males, 1 adult female, 2 yearling males, 2 yearling females, and 1 male fawn) were roadkilled during this study. The deer population on No Name seemed to have increased during this study. An adaptation of the Lincoln Index to observations of deer seen on No Name during April-June, 1973 yielded an estimate of 34 animals.

Little Pine Key Complex. This complex consists of Little Pine, Big and Little Johnson, and Grassy Keys (Figure 3); these are all outlying islands. Deer were observed on both Little Pine and Big

Johnson Keys and fresh tracks were observed on Little Johnson and Grassy Keys. Both Johnson Keys yield considerable deer sign as evidenced by current trails, pellets, and browsed plants. A total of at least seven deer were observed on Big Johnson during the study. One was impressed by what appeared as dark, large-sized animals; these observations suggested the necessity for more study of deer on the outlying keys. Both Johnson Keys have a network of open areas and an interior of near-hammock and hardwood "islands" of cover with considerable usable deer habitat. Variety of plants is lacking, as well as abundance of given kinds except for the mangroves. Little Pine Key contains all major vegetation types and offers considerable habitat and food supply for deer support. Numerous deer were sighted on this Key and fawn tracks indicated reproduction had occurred. Grassy Key has vegetation similar to the Johnson Keys but, in addition, has a sizeable, typical hammock area.

A trip to Big Johnson Key during the height of the 1970-1971 drought found all water holes dry except one. A deer was sighted near this water hole and heavy deer use was apparent around it. This site yielded little exposed surface water, as most of the stored water was in a large cistern-like cavity in the side of the basin. This allowed for minimum evaporation and probably accounted for the presence of water following the dry season. An alligator also made use of this hole and used the cistern for its home. In December of 1972 this water hole was found to be brackish due to high fall tides. At times of low rainfall, quality of such water on keys with low elevations is affected by the intrusion of salt water via tidal

changes. Water holes on Grassy and Little Johnson Keys were believed dry during the height of the drought; Little Pine Key was believed to provide some acceptable water during the entire drought. Deer probably returned periodically or regularly to Little Pine Key when water holes on Grassy and Little and Big Johnson Keys went dry or became too brackish. A 2-year-old doe skeleton was found on Big Johnson Key in June, 1971 (this animal appeared to have died within the previous month). In September of 1971, a fawn skeleton was also found on Big Johnson Key. An adult doe skeleton, which appeared to be about 1 year old, was found on Little Pine in December, 1972. All skeletons were found near water holes; the deer appeared to have died during the drought. Previous trips prior to the drought always revealed numerous signs of raccoon activity on this complex of keys; however, following the drought and until the present time, no new raccoon activity was observed.

It was difficult to make an estimate of the number of deer on this complex, as deer may be on any one key at different times. However, 30 animals for the whole complex, with the majority being on Little Pine Key, would seem a reasonable prediction. At best the population on this complex remained stable throughout this study.

Big Pine Key Complex (Excluding Big Pine Key). Along with Big Pine Key, this complex includes Howe, Annette, Mayo, Cutoe, Porpoise, and the Newfound Harbor Keys. With the possible exception of Howe Key, deer using this complex were dependent on Big Pine Key for their existence during periods of low rainfall. During the drought no recent deer sign or fresh water was recorded on Mayo, Porpoise, and

Annette Keys. Even with an artificial water supply it is doubtful that these islands could support a permanent deer population. They are not high enough to provide the variety of vegetation types that seem necessary to support a resident deer population. The outer keys of this complex yield a limited variety in deer habitat with the exception of Mayo, Porpoise, and the smallest of the three Newfound Harbor Keys. Much of Cutoe Key is subjected to tidal inundation during spring and fall high tides; hence, it is of little use to deer.

At various times deer or deer sign were located on all the above keys with the exception of Cutoe and the smallest of the Newfound Harbor Keys. An adult animal was jumped on Annette during the height of the drought; however, deer sign indicated that this deer was probably on the island for a "visit". Numerous deer were seen on Howe Key. Following the drought, two deer skeletons were found on Howe; one a 3-year-old doe and the other could not be identified as the skull and lower jaws could not be found. It might be suggested that these were victims of the drought, as all were near or at water holes which were dry during the drought or which contained a high salt content. An adult doe skeleton was found in a dry water hole on Big Munson Key (the largest of the Newfound Harbor Keys) after the drought.

As many as three deer (all adults) were seen on Big Munson Key at one time; however, no permanent water supply existed. Mayo Key evidenced deer sign prior to the drought but none were believed there since. Recent sign was left by deer transplanted to this Key. During the drought an adult doe gave birth to a fawn on Porpoise Key. But, she swam to Big Pine almost daily except following periods of rain.

It would appear that deer utilizing Annette, Howe, Mayo, Porpoise, and the Newfound Harbor Keys obtained acceptable water on Big Pine Key during the drought. The population estimated for Big Pine Key during the drought may have included these animals; however, probably six animals constituted the resident population on Howe Key during this study. The average number of deer utilizing Big Munson Key was possibly three animals during periods other than extreme drought. All other keys of this complex are visited occasionally by deer which usually return to Big Pine within a few days.

Torch Key Complex. This complex includes Big, Middle, and Little Torch, Ramrod, and Water Keys, plus a small island off the southeast end of Ramrod Key. Except for the latter two islands, these keys have fair to good deer habitat. A permanent supply of acceptable water may be available only on Big Torch Key during periods of extreme drought.

Numerous deer were sighted on Big and Middle Torch Keys. Early in this study, deer were also regularly seen on Little Torch; however, with increased development fewer deer were recorded. As many as three deer were seen on Water Key at one time; but, these animals seemed transitory and probably were part of the Big Torch Key population. A male fawn was caught in February, 1969 while swimming from Water to Big Torch Key. Ramrod Key, subjected to extensive development, yielded few observations of deer. Old tracks of a single deer were twice located on the small island southeast of Ramrod Key.

Eight (5 adult males, 1 adult female, and 2 yearling males) deer were roadkilled on Ramrod Key, eight (3 adult males, 1 adult female, 2 yearling males, and 2 male fawns) on Little Torch, one adult male

was killed on Big Torch, and a male fawn was killed on Middle Torch. It was of interest that all animals killed except for two adult females (one on Little Torch and one on Ramrod) were males. All but two animals of this complex were killed on Little Torch and Ramrod Keys; however, these were the only keys of this complex crossed by the Overseas Highway. Many of these roadkills have represented animals dispersing from other keys. The estimated resident deer population for this complex of keys was 15 deer on Big Torch Key, 10 on Middle Torch Key, 5 on Ramrod Key, and 3 on Little Torch Key.

Cudjoe Key Complex. Aside from Cudjoe Key, Sugarloaf, Big and Little Knockemdown, Summerland, Toptree Hammock, and Wahoo Keys make up this complex. Good deer habitat seemed evident on Cudjoe and Sugarloaf Keys, as both provided areas of pines and sources of permanent acceptable water. These keys were being extensively developed and about 50% of the good deer habitat had been destroyed. Late in this study the last area of major pines was subdivided on Cudjoe Key. Also, Sugarloaf Key has about 100 horses which compete with the few remaining deer; and, the possibility of domestic disease spreading to the deer herd seems important. Big Knockemdown has a small stand of pines, whereas Summerland, Toptree Hammock, and Wahoo Keys have limited deer habitat; none of these have permanent acceptable water. Little Knockemdown provides little more than dense stands of inundated red mangrove.

Two roadkills recorded on these keys yielded an adult female and a male of unknown age on Cudjoe Key. Early in this study one was impressed with deer sign on Cudjoe Key; however, very little sign can

now be found. Deer sign has been observed on all these keys except Little Knockemdown Key. During 1970, an adult male was seen on Sugarloaf Key by Jack Watson, Refuge Manager. This was the first recorded sighting on this Key, although tracks were seen earlier. A trip to Cudjoe Key in March of 1970 yielded some sign of deer browsing but no fresh tracks or pellets. Deer using Wahoo, Toptree Hammock, and Big and Little Knockemdown Keys must either return to Cudjoe or Summerland Keys for the nearest acceptable water during dry periods.

The estimated population for this complex was between 15 and 20 deer. Resident animals probably occur only on Cudjoe, Summerland, Big Knockemdown, and Sugarloaf Keys. Toptree Hammock and Wahoo Keys are visited occasionally by deer from Summerland Key.

Other Keys. Other outlying keys visited during this study were Crawl, Content, East and West Bahia Honda, Horseshoe, Mud, and Raccoon Keys. Raccoon Key was the only island of this group that revealed any possible deer habitat. None of these keys showed deer sign or permanent acceptable water.

During the course of this study impressions concerning deer population stability were gained. Deer seemed to have increased on both Big Pine and No Name Keys. Populations on Cudjoe, Sugarloaf, Big, Little, and Middle Torch, Howe, and Big Johnson Keys appeared to have decreased. The Little Pine, Summerland, and Ramrod populations may have remained stable during this period. The increase of deer on Big Pine was possibly due, in part, to natural increases and deer returning to Big Pine because of the lack of acceptable water on outer keys.

The increase on No Name Key may have been the result of a natural increase responding to development of the Key and a recent fire clearing the pine community. It was difficult to understand what caused the decrease of the deer population of the keys mentioned above. Surely increased development of Cudjoe, Sugarloaf, and Little Torch aided in this decline. A decline in number of deer on Howe and Big Johnson seemed related to a lack of acceptable water during the drought. The possibility of poaching affecting numbers of deer on given keys should not be negated. Reports of hunting on Big Johnson and Little Pine were frequent. Judging from the illegal hunting of white-crowned pigeons on the Torch and Sugarloaf Keys, and ducks on Little Torch, it seemed probable that illegal deer hunting did occur. With low population levels, a few illegal kills represent an important element of control on increment, let alone any contribution to decline.

Sex and Age

Sex and age ratios of Key deer were determined for mortalities and live captures from 1968 through June, 1973; this was supplemented by field observations recorded during October, 1969 through 15 June 1972. Although Severinghaus' (1949) technique was employed for ageing, it was considered inadequate for Key deer. Deer observed in the field were identified as fawns, yearlings, or adults based on physical features. But, it was especially difficult at certain times of the year to determine the sex of yearlings, distinguish 6-12-month fawns from yearlings, and yearlings from adult females. Most accurate was the identification of adult bucks during mid-July to March when they

had fully-developed antlers. Fetal sex ratios were taken from road-killed pregnant does when possible.

Sex ratios varied depending upon the methods used to determine them. Based on 18,212 recorded observations of deer during March, 1968 through December, 1971 and during April through 15 June 1972, 13.1% were adult males, 42.9% adult females, 10.1% yearling males, 12.5% yearling females, and 21.3% fawns (Table 6). The composition of the herd varied from one year to the next and varied from month to month (Table 7). Monthly variations primarily reflected seasonal changes in behavior of the different sex and age classes.

The proportion of adult males observed increased to a peak in October, then decreased to lows in March and April. This increase was associated with activities just before and during rut and the lows occurred at times of antler loss and reproductive quiescence. It appeared that there was roughly one-third the number of adult bucks as adult does in this population.

April 1 was arbitrarily designated as the birth date for Key deer, as fawning occurred mainly in April and May. The ratio of fawns to other age classes observed showed an increase during the year, especially when older fawns increased their movements into open areas. Observations of fawns in open areas alone or with does generally did not occur until June or July; however, this varied with weather and number of insect pests. A drop in the ratio of fawns to does in March reflected the disassociation of fawns and adults preceding and during parturition of new fawns. Harassment from older deer may have tended to keep old fawns out of open feeding areas, and thus out of sight of the observers.

A decrease in the ratio of yearlings to adults in September and October reflected behavior changes during breeding seasons, especially of yearling bucks, which often left their home ranges. Both bucks and does decreased use of open areas somewhat. A secondary drop occurred in March when does drove yearlings from their ranges as they gave birth to fawns. The ratio of yearlings gradually decreased throughout the year as they left their home areas, at which times they were often not seen again; and, many were killed on roadways.

The ratio of deer observed does not reflect the actual herd composition; rather, over many years it probably reflects trends in population dynamics (Table 6). The ratio of adult males to females and fawns to females decreased during the later years of the study. Care in interpreting these data is necessary, however; for example, data excluding some months cannot be compared to data incorporating those months due to differences in behavior. Since the 1972 data does not include a complete year, sex-ratio values cannot be compared.

There was an apparent increase in the percent composition of the adult age class, with a decrease in the fawn category during the 5 years. Such a condition may result in a population which does not increase rapidly and which may show signs of stability, or even decline if mortality is high.

The sex ratio of deer captured is biased in the older age classes as most deer in open areas where captures occurred were marked early in the study, and thus were not selected for in later years (Table 4). With the exception of occasional captures of new adults, most new captures involved fawns and yearlings. Thus, the

age structure and sex ratios taken from capture tables are not accurately depicted with the possible exception of the sex ratio of young fawns.

Fawns were captured at a ratio of 2.41 males to females. Fawns 1 day old or less were captured at a ratio of 2 males to 1 female. Fawns during April and May were captured at a ratio of 1.75:1 and during the remainder of the year at a ratio of 2.72 males per female. Despite the small sample size, there appeared to be a trend of increased males in the herd, either due possibly to higher mortality of newborn doe fawns, or due to behavior differences resulting in bucks being seen and captured more frequently. Since males and females had slightly different amounts of activity at different ages (see Deer Activity Patterns) this possibly accounted for differential trapping and mortality, thus magnifying the actual difference that existed in fawn sex ratios.

Behavior of animals greatly influenced sex and age data available from roadkills (Table 8). In addition to more male fawns, which may really exist, the ratio of adult males and yearling males to females was a reflection of greater male activity and movements in areas of heavy traffic, especially during breeding seasons. As bucks were selected out at a greater rate, this resulted in a large proportion of females in the older age classes remaining in the herd.

The sex ratio of fetuses should be reasonably accurate; however, small sample sizes may have resulted in distortion. Male fetuses outnumbered female fetuses 1.45 to 1 (Table 9); the ratio of males to females increased during the 5-year study, varying in different

years. Such predominance of young males slowed the rate of population increase as bucks provided much of the herd mortality, they did not contribute additionally to the reproductive output in this polygamous species, and their aggressive behavior as adults during the breeding season caused dispersal and lower levels of actual breeding.

Life Expectancy

The structure of a population is determined by the age specific birth rate, the sex ratio at birth, and the mortality for each specific sex and age class. A total of 110 Key deer (55 males, 55 females) which were marked for varying periods of time were either known to be alive at the end of the study or died at a known age. Based on the age of these animals when captured and the age at which they died, a survivorship table was developed based on the percent of animals in each age class that were known to have survived into the next age class (Table 10). April 1 was considered the birthday for each animal.

Both males and females showed a high mortality rate (observed) during the first 6 months of life; most mortality occurred during the first few days after birth, chiefly through drowning in ditches (Figure 4). Females had a slightly lower survival than males up to 1 year; but, thereafter they showed an improved survival rate. No males were known to live beyond 8 years of age, and no females were known to live beyond 9 years. Fifty percent of the males survived to 1½ years while females showed a 50% survival to around 2 1/8 years.

A weakness in this model was the accurate ageing of deer over 2 years in age. The use of tooth wear and replacement criteria was

not believed especially appropriate for Key deer. However, those captured as fawns and yearlings were accurately aged. There was also the possibility that survival of marked animals was different from that of unmarked animals. Any adult deer known or suspected to have been a capture mortality or known to have died due to marking devices was eliminated. Too, it was possible that some very young fawns died due to being moved or abandoned by the doe because of disturbance caused by the observers; however, this was not believed to be greatly different than for unmarked deer in the same areas or in other areas where the human population was high.

Using the age specific survival, the birth rate, the sex ratio at birth, and the sex-age structure of the population, a model population was simulated (see Water Availability and Utilization). Such calculations seemed necessary in determining the potential of the population and establishing the probable changes that should be anticipated under the conditions affecting the quality of the Key deer range.

Mortality

During January, 1968 through June, 1973, 304 mortalities were recorded for Key deer on 10 different islands. Sixty-five (21.4%) involved marked or captured animals. The main known cause of mortality was collision with automobiles, followed by drownings (Table 11). Remains of seven (2.3%) adult bucks with holes in the skull between antlers or with other severe injuries suggested that combat with other bucks was probably involved in their deaths. Various unknown causes accounted for 8.6% of the losses. These included remains of four adult does, one adult buck, one fawn, and a deer of

unknown sex and age, which were found in or near dried water holes on Howe, Big Johnson, Little Pine, and Big Munson Keys. Six of these deer were found just after a severe drought in 1970 and 1971; all may have succumbed to the harsh conditions on these outlying islands during drought.

One 2.2-pound fawn may have been abandoned after marking or may have been too small or weak to survive; another appeared to be the weaker of a set of twins. Three deer which may have sustained natural or handling injuries were believed killed by free-ranging dogs.

An additional 2.6% of the mortalities were attributed to miscellaneous factors, including two yearling males and one yearling female that were injured while attempting to escape from fenced areas, and three fawns that were possibly abandoned or lost, two of which were moving alone through the woods when found. A 6-month-old fawn was found in a dry solution hole.

Capture mortalities, which accounted for 5.9% of the deaths, included six deer (3 yearling females, 1 adult female, 1 yearling male, 1 male fawn) killed from overdoses with nicotine salicylate, one adult male killed in a net trap, three males (1 yearling, 1 adult, and 1 fawn) that were injured when they hit the truck, and three deer (1 adult male, 1 adult female, and 1 male fawn) that were injured when they hit the capture net. One adult doe developed a severe infection and became blind after wearing a collar that was too tight, and one adult male may have died because of a tight collar. Three fawns and a yearling buck died after getting legs caught in loose collars.

Highway mortalities, most of which occurred on Big Pine Key, accounted for the major portion (76.0%) of the dead deer (Table 5). Thirty-four (14.7%) of the roadkills were marked. Most deer (87.0%) were killed on Big Pine Key while 4.3% were from No Name, 3.5% from Little Torch, 0.4% from each of Middle Torch and Big Torch, 3.5% from Ramrod, and 0.9% from Cudjoe. From 1968 through 1973 there was an increase in the number of roadkills off Big Pine Key. Although this may suggest a reoccupation of the former deer range, land development and other human disturbances are extensive, causing change in areas used by deer on these islands.

Nearly half (46.8%) of the deer killed on Big Pine were on the Overseas Highway (US 1), 28.4% were on State Route 940, and 24.9% on other roads. Statistical analysis of data from 1968 through March, 1971 showed that 1- and 3-year-old males were more likely to be killed on the Overseas Highway than females of the same age; and, female fawns were more likely to be killed on State Route 940 than male fawns. The proportion of animals killed on the Overseas Highway and in other areas varied, partly due to a displacement of animals in response to extensive habitat changes resulting from land development, especially along the Overseas Highway and State Route 940. Deer fed on mowed roadsides in early morning, evening, and at night, and bedded in nearby cover. As land was cleared along the highways, deer lost their cover and tended to shift their activities. In 1970-1971 a decrease occurred in the ratio of deer killed on the Overseas Highway to those killed on State Route 940 and other roads. During much of 1970 and the first half of 1971, a severe drought resulted

in a scarcity of fresh water on the south end of Big Pine Key. The change in location of roadkills may have reflected the shift of deer to north Big Pine Key, away from heavily traveled highways. Thus, more animals were killed on other roads. An increase in deer killed during the drought years may have reflected simply increased movement in search of water; but, an actual increase in the population on Big Pine seemed to have occurred as deer moved from islands lacking fresh water to Big Pine (see Water Availability and Utilization). As subdivisions developed and were occupied, increased traffic on secondary roads, such as State Route 940, resulted in more deer being roadkilled other than on the Overseas Highway.

It was of interest that years of high numbers of roadkills were followed by years of lowered mortality. Data for 1973 included those killed through June, and it appears that 1973 would have again been a year of high mortality. Following a year of high mortality it possibly may require about a year or so for the population (niches reoccupied) along roads to recover to the point that a larger number of deer will again be killed, resulting in a cyclic effect.

Mortalities occurred every month of the year, with most occurring in November, April, and May. These peaks tended to correspond to times of breeding and its associated increased activity, and fawning when animals were moving more due to pressures from adult deer. Roadkills also varied with the time of day, although deer were killed at all hours. The peak in mortalities occurred around 0600 to 1000 hours. Although this did not correspond to a normal feeding peak or to the peak activity in open areas, it did represent an overlap between a time of moderate deer activity and moderate to heavy

automobile traffic, the result being a large number of roadkills (see Some Behavioral Patterns). The least number of deer were killed around 0300-0500 hours when deer activities were slack and human activity was at a low, and again in mid-afternoon when deer generally remained in cover, away from human activities. A slight increase in mortalities occurred in early evening, corresponding to the evening feeding periods in open areas.

There was an obvious differential sex mortality ratio with males being roadkilled more frequently than females (ratio of 1.74:1 males to females) (Table 8). This resulted from a greater number of males in the population and a difference in behavior between males and females, with males moving about more in open areas after 2 to 3 months of age. These activities occurred especially in April, May, September, and October when new fawns were born and breeding began.

Accounting for 4.6% of the mortalities were deer that drowned, chiefly newborn fawns. Many fawns were born in areas completely surrounded by mosquito ditches. These drainage ditches were designed to connect water holes that served as potential mosquito breeding sites to the salt water channels, allowing fish to get into these holes and allowing for some flushing action with the tides. Many of these ditches were of sufficient depth that a deer which fell into them could not escape. While a 2-3-week-old fawn could jump across these ditches, a very young fawn attempting to cross often fell in. Of 33 marked newborn fawns, 6 (18.2%) drowned in ditches. In addition, remains of five unmarked fawns were found in these ditches and four fawns were rescued from ditches that were isolated and nearly dry, or that had little water during low tide. Three of these fawns

fell in on two different occasions, one drowned the second time. Although traps set on four ditches during 1973 failed to collect any fawn carcasses, evidence suggested that dead fawns may often be flushed out of the ditches into the channel with outgoing tides and thus never found. Other fawns in blocked ditches or on side ditches no doubt quickly deteriorated in the warm stagnant water, and were devoured by fish, crabs, and alligators. Two fawns that had fallen into ditches had portions of their flesh eaten away by crabs in less than 12 to 18 hours, and partial remains of three other fawns were found in stagnant side ditches.

Big Pine alone has more than 100 miles of ditching. Although deer generally did not move young fawns great distances, in certain areas of extensive ditching any movement jeopardized the fawns. No doubt some does moved their fawns after being disturbed, and the 18.2% mortality recorded may have been a slight exaggeration; however, it was not believed to be greatly different from actual mortality of unmarked deer in the same areas or in other areas of high human activity. It is believed that fawn mortality due to drowning in mosquito ditches was rather frequent in ditched areas of Big Pine Key.

Insect pests may have also posed a hazard to deer, especially fawns. In 1971 and again in April, 1972 and 1973, the relatively dry conditions resulted in mild infestations of mosquitoes; however, in 1968-1969 and 1969-1970 after heavy rains, insect pests were such that deer regularly moved along the roadway and to open areas to bed in a breeze and escape mosquitoes that remained in thicker cover. It was not uncommon to see deer of all ages moving to open areas, the head and legs covered with mosquitoes and even blood spots around

the eyes and on the face. In such years it was not inconceivable that mosquitoes could have caused enough loss of blood in small fawns to result in illness and death. Evidence from mortalities to substantiate this, however, would be difficult to determine even if such animals could be found.

During the study deer were often seen with various injuries, especially after the breeding season. Adult bucks had broken antlers, exposed and fractured skulls, and open sores and cuts. Four dead bucks with holes in the cranium between the antlers and one live male with loose bone fragments on an exposed part of the skull evidenced severe battles between bucks.

Deer were also seen with what appeared as broken legs and later close examination generally revealed a swollen but healed bone. Solution holes no doubt pose the threat of broken legs; however, some of these may have been hit by a vehicle.

During the dry season deer on outlying islands, where fresh water is not available throughout the year, must swim to nearby keys having fresh water. Weakened deer or very young deer unable to swim may succumb during periods of drought. Such may explain the five skeletons found on outer keys. Swimming the shark-infested, often swift currents in channels also probably serves as a mortality hazard.

One doe was found that had lost half of her udder in some previous accident, and an adult buck was caught that had golf ball-sized skin tumors on the neck and shoulders. These fibromas, which have been described in other deer (Karstad 1962) were absent when recaptured a few months later.

Two deer were found to be partly blind, an adult doe and the other an adult buck that had one eye completely glazed over. In addition, an adult doe became blind after an infection occurred due to a tight collar.

The number of roadkilled deer, the substantial number of fawns drowning in ditches, and the mortality on outlying islands during drought years, coupled with lowered reproductive output has apparently resulted in the population of Key deer reaching a more or less stable condition, with death rate nearly equaling birth rate. It appears that all the above factors have contributed to prevent the rapid overproduction of deer in this habitat which is characteristic of other deer for which controls become suddenly unbalanced. The result in the Key deer has been a gradual increase in past years and a gradual leveling off to present. Drastic sudden changes could shift the population in either direction, resulting either in rapid increase or decrease in numbers, either of which could have ultimately disastrous effects on the deer herd.

Breeding

Aspects of behavior associated with breeding and fawning were emphasized to note their effects on the population dynamics of the herd and to serve as a basis for development of management programs. Data were obtained on the date and time of day when breeding occurred, as well as the associated behavior and the sex and age of deer involved. Animals of various age and sex were radioed prior to the breeding season to facilitate detailed studies on behavior and to determine specific roles in breeding. No adult males wore functional

radios during September through October of 1969, but some carried radios during the 1970-1971 season.

Reproductive activities were difficult to monitor as they often occurred in thick vegetation; also, during the precopulatory activities, bucks often chased does over large areas and such movements precluded close observations. Since does normally bred but once a year but males serviced numerous does, an effort was made, through radio contact, to stay with mature males. The few adult males accessible for capture just prior to the rut and the rough behavior of running through thick vegetation and fighting, which quickly damaged radios, resulted in a limited knowledge of some breeding activities. However, penned animals provided opportunity to observe several basic reproductive patterns.

During 1969-1970 most reproductive data were by way of observations of marked and unmarked deer. The most complete data on breeding were obtained in 1970-1971 when at least seven bucks high in the hierarchy retained radios throughout the breeding season. To complement field observations, reproductive tracts from mortalities were saved for later examination.

The earliest observation of females being harassed by adult males was on 24 August 1971 when two bucks in velvet chased a doe and yearling briefly while feeding. But, actual breeding behavior involving bucks with polished antlers was not seen before 6 September (Figure 5). Following loss of the velvet, adult males increased their harassment of all deer encountered; also, numerous mangled shrubs evidenced increased buck activity. Breeding activities

increased in late September, peaking in early October. There was a gradual decrease through November and December; and, occasional sightings of bucks nose-trailing or harassing females occurred into February. However, most breeding was accomplished by early November; and, subsequent observations primarily involved bucks chasing unreceptive females.

Adult animals with full racks were generally the earliest breeders, as those with lesser racks and yearling males were excluded by larger, aggressive bucks. In those few instances when yearling and fawn does appeared receptive it was later in the season. For those observations in which the sex and age of participants could be determined, yearling males were involved 3.9% of the time in October, 25% in January, and 57% in February. Yearling does were involved 14.5% in October and 37.5% in January; and, most were probably bred. Fawn does were involved in only 1.3% of observations in October and 57.1% in February. However, many of these observations were merely chases in which males harassed females, although yearling does were bred; and, some limited precocial female fawn breeding was indicated. Male fawns did not appear to participate in breeding activities.

The extent of female fawn participation appears to have decreased during the study. Twenty-nine percent of the observations in 1969 involved doe fawns, whereas only 2.0% and 3.4% involved female fawns in 1970 and 1971, respectively. This seemed to suggest that there might have been some confusion in 1969 of the fawn and yearling female age classes; experience later clarified this. However, it probably reflected an actual decrease in the reproductive output in recent years as suggested by other aspects of the deer's life history.

An increase in the age of first breeding due to a decrease in the number of fawns breeding would result in reduction in fawn production and, therefore, a slower rate of population increment.

Adult and yearling males generally left areas occupied during the spring and summer, often moving to entirely new locations. When a chase involved a receptive female the males remained with her, often more than one male being involved in the chase. Competition between males for a receptive female generally resulted in threats or brief pushing bouts; only infrequently did this result in combat severe enough to cause injury, especially early in the breeding season. Adult males stayed with receptive females from 1 to 6 days; but, more usually 2-3 days. After copulation interest waned, a different receptive female was then pursued.

Key deer, like other white-tails, exhibited some sign-post type behavior of mangling and rubbing shrubs; but, territorial activity seemed limited to defending a receptive doe from other bucks rather than fixed areas. When the number of receptive does became limited in November or December, almost any encounter between males resulted in combat. This often precipitated minor injury and occasionally death to one of the participants.

Bucks appeared not to attain a sufficient hierarchy level for full participation in breeding until at least 3 years of age. Two-year-old males had opportunity to breed does only in the absence of older, larger animals. After 5 years their dominance appeared to diminish; males 7 years or older and yearlings appeared to be excluded by 3- to 5-year-old animals when encounters occurred. The

role of the younger males progressively increased in significance during December through February.

It seemed unlikely that the exclusiveness of adult bucks in breeding does during the peak in October resulted in many does not being bred. Does not serviced or in which conception did not occur entered a second or third estrus. Observations of a penned adult female having an injury that precluded conception entered as many as four estrus periods at intervals of 25 to 27 days. By such recycling all females entering heat and capable of conception would probably be bred successfully. Such repeated cycling undoubtedly resulted in fawns being dropped over an extended period and contributed to the animals observed in the population which were of varying ages and sizes.

Due to the extensive movements by adult and yearling bucks during the breeding season, it appeared that little genetic isolation due to spatial mechanisms occurred on any given island, as movements from extreme ends of the island by males were not uncommon during this period. However, genetic isolation due to spatial separation is undoubtedly promoted in populations which occupy widely separated islands. There was no evidence suggesting movement between islands during the breeding season.

Histological Analyses

Epididymal and testicular tissue slides from 22 Key deer were examined to determine fertility and reproductive status. The degree of spermatogenesis observed in the 10-micron cross sections provided the basis for evaluation and measurement of tubule activity. The

resulting data were assigned to one of four categories based on the degree of development. In the prepubal young the tubules were simple and undeveloped with the germinal eipthelium consisting only of spermatogonia and Sertoli cells. A similar state occurred in the testes of adults during the non-breeding or quiescent period. Eight specimens, exhibiting development consistent with the immature or quiescent stage of spermatogenesis, were placed in Category I. Category II reflected some slight development, but it was incomplete with few or no spermatozoa present, and represented either an immature stage or a quiescent stage. Three animals were assigned this status. Category III represented moderate development of spermatogenesis in which some of all stages were present. The six specimens which were placed in this category were probably at the beginning of the breeding season or near the end of it. In each case, spermatozoa were present in the epididymides and all stages of spermatogenesis present in the seminiferous tubules. Category IV, to which five animals were assigned, identified the state of full spermatogenic activity, with high development of all stages present.

Spermatozoa may be present in the epididymis of an animal whose testes have stopped proliferating since sperm pass quickly from the lumen of the seminiferous tubules into the caput epididymis where stored. Thus, there may be a fairly long lag period between the presence of sperm in the cauda epididymis and the cessation of sperm production.

It appeared that some spermatogenic activity began as soon as late July or early August; but, it was concentrated most heavily in

October and November (probably December but no specimens were available). Some spermatogenesis also appeared to occur as late as April.

Fawning

Pregnant females were radio-marked in February and March and observed for documentation of reproduction and fawning activities. Attempts were made to determine behavior of does associated with fawning, the number of does breeding, when and where fawns were dropped, number of fawns per doe, and to mark newborn fawns for behavioral and activity study and to serve as known-aged deer in the future.

Adult does appeared to interrupt their daily routines only briefly when fawning. They separated themselves from yearlings and moved to an area affording a more open understory. Birth of fawns occurred in all habitat types including semi-open pinewoods and on small areas of dry ground within a damp mangrove thicket.

The first recorded birth of a fawn was on 1 April; however, the appearance of large, more mature fawns suggested that some were born in mid- to late March. Peak parturition occurred in April, tapering off through early to mid-May. Observations of "heavy" does and highway mortality of pregnant does in mid-summer indicated that fawns were occasionally dropped throughout the summer. One yearling doe was known to have fawned in August. Fawns conceived during second or third estrus periods or born to late-breeding yearlings and fawn females, yielded fawns of varying size throughout the year. This variation resulted in some confusion in ageing these animals.

Because April was the peak in fawn production, 1 April was considered the annual birthday for all Key deer.

Based on four does for which breeding and parturition dates were known, the length of gestation was 201, 201, 202, and 204 days. This was similar to other white-tailed deer for which gestation periods have been determined.

At birth fawns weighed from 2.2-4.5 pounds; most weighed around 3.5 pounds. They were immediately active after birth and were able to walk and slowly follow their does within 1 hour. After the first day, fawns spent little time with the does, nursing briefly 2-3 times a day, and remained bedded the rest of the time. At 2-3 weeks they spent more time with the doe at each feeding, moving briefly before bedding and gradually covering areas of the doe's range that provided cover. At 4 weeks they moved some alone in familiar areas, occasionally browsing plants.

As fawns matured and increased their movements, does spent increasing time looking for them so that by 2 months they encountered one another every couple of days. At this age fawns attempted to nurse any large deer; but, no does with marked fawns were ever seen to accept fawns other than their own. Most strange fawns were forcibly driven away by kicking. Recognition appeared to be mostly by scent, and fawns characteristically presented the perianal region to the does while nursing, as does sniffed and cleaned them. Evidence suggested that does which lost fawns occasionally adopted very young fawns belonging to other deer. A fawn belonging to a 2-year-old doe apparently drowned while following another marked doe. Whether this fawn was abandoned and then adopted by another deer, or simply attracted

the strange doe by its distress cries was not established. It was possible that the young dam may have been driven away by an older, larger doe.

By July fawns spent time browsing in open areas and by September weaning was generally complete. However, an 8-month-old roadkilled fawn had curdled milk in its stomach. There appeared to be a strong doe-fawn bond as adult females that lost fawns demonstrated fawn-calling behavior for several days. One adult female that had a fawn on Porpoise Key, an island without fresh water, swam the 0.8-mile channel every other day to Big Pine Key for fresh water. After drinking and feeding, she returned to Porpoise after about 6 hours. Following heavy rains such movements were temporarily discontinued. Another doe from Big Pine Key swam Bogie Channel daily to No Name Key where she was known to have a fawn. Does and yearlings of family groups were more tolerant of fawns belonging to other members of the same group, but frequently drove unrelated deer away. Does chased their yearlings away by gently shoving with the head; whereas, unrelated deer were driven out forcibly using the front feet to kick them. Despite some antagonism toward "family" yearlings and older offspring, does generally reassociated with yearling does and occasionally yearling males following parturition.

Antagonism toward other deer by adult does with new fawns may serve to permanently disperse females as well as males from home areas. If a displaced doe should happen to fawn before returning to her "home" area, she would probably reestablish her range in the new area. Such movements as that of the adult does to Porpoise and No

Name Keys and the apparent permanent shift of an adult doe to No Name Key may be a result of population pressures during or just before parturition. Due to such pressures, it is not inconceivable that female deer, generally considered relatively stationary, might move to new islands and stay if conditions were suitable.

Management techniques that result in habitat disturbances should be avoided during April through mid-summer to allow fawns to mature enough to escape danger and survive should they be separared from does. Also suitable, adequate cover for dropping fawns and for bedding sites should be left in all areas managed for deer.

Although does generally did not abandon fawns despite handling and marking, a couple of marked fawns died possibly after being abandoned. Several does were displaced from the north end of Big Pine Key in late April during military maneuvers and any young fawns could have been lost or could have died during this time. Such practices on Refuge lands should be avoided, especially at that time, if maximum survival of fawns is to occur.

In Key deer there was some evidence of limited precocial female fawn breeding; however, this was probably less common than apparent from observation data (see Breeding). The fact that fewer doe fawns were involved in the breeding activities during the last 2 years of the study suggested that the population was experiencing a slowed rate of increase.

Based on mortality data for Key deer, there seemed to be a relatively low reproductive rate. No females examined under 2 years of age carried fetuses or were lactating at the time of death; and,

only three (60%) of five pregnant 2-year-old does killed on the highway had bred as yearlings. Of 41 adult females examined, 35 (85.4%) appeared reproductively active (including both pregnant and lactating does), producing a minimum estimated fawn count of 1.02 per doe. This was based on deer examined throughout the year; but, breeding began in September and fawns dropped 200 days later. Therefore, does killed from November through June should have had noticeable fetuses or else have been lactating if they reproduced. Of 35 does, 2 years old or older, examined during November through June each year, 31 (88.6%) were reproductively active. This included 19 (54.3%) carrying single fawns and 7 (20.0%) with twins; 5 (14.3%) were lactating indicating they had produced at least 1 fawn each (Table 9). These data provide a minimum count of 1.08 fawns per adult doe. This finding generally agrees with reproductive rates reported by Harlow and Jones (1965) for other south Florida deer herds.

Based on observations during September, 1969 through December, 1972, of 114 marked does that could have had fawns during these 3½ fawning seasons, 71% were seen with fawns. During 1970 and 1971, which were full years of observations, 32 (76.2%) of 42 does and 38 (64.4%) of 59 does, respectively, were seen with fawns. These numbers could be conservative for some fawns may not have used open areas with their does; however, they are probably liberal since fawns were often seen with deer other than their own dams. If these biases are minimal, given that 90% of the does bred and given that roughly 70% of the does successfully produced fawns, this would indicate roughly

a 20% mortality between preparturition and 4-6 months of age when fawns appeared to move with does. Survivorship of marked fawns indicates a higher mortality rate in the 0-6-month age class than this (see Life Expectancy).

The occurrence of twins was comparable with other south Florida deer herds (Harlow and Jones 1965); 28% of those pregnant had twins while 72% carried single fetuses. In addition to low rates of reproduction, the fawn sex ratio favored a slowly increasing or stable population with male fetuses outnumbering females (see Sex and Age).

Young does appeared to be less efficient than older ones. A 2-year-old doe upon giving birth did not clean her fawn, eat the after-birth, or call to her fawn as it walked away, as was characteristic of older does. This young doe did stay with the fawn and allowed it to nurse, until it fell into a mosquito ditch and drowned. Another 2-year-old doe apparently abandoned her fawn or was chased away by an older doe who appeared to be caring for the newborn fawn when it, too, fell into a ditch and drowned.

Although does generally did not move fawns extensively the first few days, any disturbance to the doe in the vicinity of the fawn resulted in a shift in location of the fawn. This increased chances of mortality, especially in areas of extensive mosquito ditching and roadways.

DEER ACTIVITY PATTERNS

Movement and Range

During 1969 through 1970, radio-tagged deer were located at least once each day at randomized hours; this permitted determination of certain aspects and patterns of movement and range utilization. All radio-determined locations were plotted on base maps of Big Pine Key to provide a record for each individual Key deer tracked. The average distance in feet between each successive daily radio-location was used to determine, by measurement from the base maps, a movement index. This index was not meant to measure total movements in feet that a given animal moved per day, but was an index to its movements when compared to other individuals of the same and/or different age and sex classes.

The size of ranges by month and major and minor axes of ranges were calculated for all deer for which there was established more than 15 locations per month. The size of range was established by connection of the outermost locations of each animal with a straight line and computing the area with a compensating polar planimeter. All water areas except ocean were included. Visual observations were used to supplement determinations of ranges. The major axes were determined by measuring a straight line that connected the two most distant locations for each animal. The minor axes were established by measuring a straight line perpendicular to the major axis and connecting the boundaries of the range at its widest point.

The major and minor axes provided an indication of shape for each range. However, the size, shape, and utilization of vegetation

types of the range were influenced by the physiographic arrangement of the habitat and varied with the portion of the key the animals inhabited, individual requirements of each animal, and population level.

Results

During this study 12,328 locations as determined by radio-telemetry were recorded for 81 different deer. These represented 12 adult males, 21 adult females, 5 yearling males, 2 yearling females, 27 male fawns, and 14 female fawns (ages at time of capture). In addition, data were available from over 10,000 sightings of the 223 marked deer.

By combining movement and range data for animals of various sex and age classes (Tables 12 & 13), various aspects of deer activities and life history could be correlated. Movement indices for adult males were found to be largest during the rutting season (October through December) and lowest during July when there was maximum regrowth of antlers. During other periods of the year, movement indices were nearly the same except during April, at which time there was a substantial increase in size of the range. This corresponds with the reproductive season, at which time adult does with newborn fawns were actively running any other deer, including adult bucks, from the immediate area of the new fawn.

Indices suggested that beginning in September, adult does revealed increasingly larger ranges; this reached its peak during November when the breeding season was at its highest level. Much of such movement was probably influenced through harassment by males.

During the rest of the year, movement indices were quite similar except during the period just prior to the dropping of fawns, when adult does showed reduced movement and area utilized.

Yearling males showed an increase in the area of use at the commencement of the rut, reaching a peak during the height of the rut in November. These animals gradually exhibited reduced ranges up to the fawning season when size of area used declined sharply and leveled off for the summer months. Yearling males showed larger movement indices than any other sex or age group.

Yearling females tended to show rather stable ranges for the entire year; but, two peaks could be identified. One peak occurred at the end of the breeding season in December when a few animals were being harassed by bucks; the other occurred in May when they were forced from normal ranges by their mothers with the arrival of newborn fawns. It was during this period of the year that most yearling does first left their mothers; but, most returned within 1 to 2 months after the adult doe fawned.

In general, movement indices for fawns of both sexes showed an increase as they grew older. During the first 2 weeks of life there was little movement except when "moved" by the doe. For the first month of life, fawns stayed close to where the doe had left them, and size of area used reflected only the doe's placement of the fawn from day to day, which in turn was affected by the habitat of the doe's range. If the fawn and doe were undisturbed, the fawn was more likely to spend a greater period of time in a given area before it was moved to a new site. At 1½ or 2 months fawns were apt to wander alone in the area where left by the doe. As they became older there

was some wandering back into old, familiar areas without the doe. Fawns up to 2 months of age did not move at night, staying bedded. After 4 to 5 months of age, areas used by fawns tended to duplicate closely that of the adult female. During the rut, fawns became "lost" from their mothers, and at this time movement was the greatest. Following the rut, most female fawns returned to their mothers and movement indices of the two were similar; however, most male fawns did not return. Those that did return usually tended to break association with the doe prior to fawning the next year.

Range data recorded over the same period as movement showed results similar to that noted for the monthly movement indices. Results for range data were not considered as good as movement data when interpreting life history data. First, all consecutive daily locations could be used to obtain movement indices; and, no matter how few this was for a given deer, it was still representative of that animal. However, ranges varied with the number of locations for a given animal for a given month. Just how many radio-locations would be sufficient to establish an accurate monthly range is questionable. Second, a few "exploratory movements" outside a "normal" range added greatly to the total area when determining monthly range data; but, such movements, when made over a period of days, probably would not influence the daily movement indices. Obviously, too, if made in 1 day, these would average out with all other consecutive daily movements and yield a more accurate picture of monthly movements. Third, range size for certain animals might not vary from month to month, but length of movements within the range would, thereby a false impression would be given of true monthly movements

if only ranges were considered. For these reasons the mean monthly movement indices were considered superior to monthly ranges as the best source for correlation of life history data.

During this study, numerous deer made long trips from their "normal" ranges either to later return or to set up "new" ranges elsewhere. The longest movements from the point of original capture were 7 miles for both an adult and yearling male. The longest move recorded for an adult doe was 5 miles, and a yearling doe 4 miles. Fawns usually did not make extended movements from their range; however, one male fawn was located over 1½ miles from his capture site. The longest move made in a 24-hour period was by a yearling male. He was sighted at Refuge headquarters at 0530 hours on 17 September 1970 and again at 2315 hours in northwest Port Pine Heights Subdivision. In a period of 17-3/4 hours he had moved over 4 miles, an average of 1,190 feet per hour. Many of these long movements were considered dispersal, as in many cases there was not a return to "original" home ranges.

Habitat Use

This telemetry study emphasized monitoring radioed deer each day and night period (24 hours) at random intervals to evaluate utilization of the major vegetation types. Each 24-hour period was divided into six equal 4-hour segments; and, one 4-hour segment was randomly selected for establishing the location for all radioed deer. All radio-determined locations were plotted on base maps of Big Pine Key; these provided a history of activity and land use of each individual Key deer bearing a radio.

All determined locations were placed on IBM data sheets and then punched on IBM punch cards. Data recorded for each individual radioed animal included deer ID number, sex, age, date, time, vegetation type, weather (cloud cover, rainfall, maximum and minimum temperature, and wind speed and direction), and behavior.

For this report, locations of individual animals were arbitrarily separated on a day-and-night basis with such delineation based on the official time of sunrise and sunset. Final analyses of these data will separate such information into hourly segments. All radio-locations were evaluated by determining the frequency of locations (of deer) as to various plant cover types. Such plant communities were based on vegetational mapping by Mr. Steve Johnson, Student Trainee, U.S. Bureau Sport Fisheries and Wildlife, Summer 1967. Mr. Johnson's work was updated to reflect land development through December, 1968. Further, habitat changes due to more recent developments have been identified by comparing this map with data compiled during June, 1973. Changes in cover types during this latter 4½-year period have been analyzed to determine the current yearly rate of land development for Big Pine Key (see Habitat Change).

A total of 11,599 random radio-determined locations were recorded for 81 deer representing 2,660 locations for 12 adult bucks, 4,414 locations for 21 adult does, 1,240 locations for 5 yearling bucks, 1,205 locations for 2 yearling does, 1,363 locations for 27 buck fawns, and 716 locations for 14 doe fawns. Sufficient locations for each sex and age group were available for adequate analysis, except for fawns during October through March. Fawns were

radio-tracked during this period, but the number of locations and/or animals tagged were insufficient for clear indication of vegetation utilization. Data for yearling females at all periods may be weak because of the few animals tracked. Of the 11,599 locations, 5,563 represent the daytime period and 6,036 the night-time.

For this report, the vegetation of the Refuge on Big Pine Key was divided into five types: developed areas (subdivisions and roadsides), pine lands, buttonwood-scrub mangrove, hardwoods (including hammock), and dense mangrove (mostly red and black mangrove). This area consisted of 18% developed area, 32% pine lands, 31% buttonwood, 10% hardwoods, and 9% mangrove.

Using data from all radio-determinations of all deer during all periods of the year, 13% of the locations were in developed areas, 34% in pine lands, 23% in buttonwood, 20% in hardwoods, and 9% in mangrove areas. When use of habitat by deer was correlated with available habitat, the data indicated that deer selected for pine and hardwood habitats and against buttonwood and developed habitats. Mangrove habitat was utilized at a level reflecting its availability. This utilization of vegetation types, when broken into night and day periods, revealed deer selected for developed habitat by 3%, pine habitat by 1%, and hardwood habitat by 5% during night hours. During this time, buttonwood and mangrove habitats were selected against by 10% and 1%, respectively. During daylight hours pine, hardwood, and mangrove habitats were selected

for by 3%, 14%, and 1%, respectively; in contrast, buttonwood (by 6%) and developed habitats (by 13%) were selected against.

Results from data compiled as to time of year, time of day, and age and sex classes (Table 14) indicated all animals for the yearly period utilized developed areas more at night than during daylight hours. Fawns were a noted exception because they were not active at night during the first few months following their birth. Adult bucks tended to utilize developed areas much less at night during October-March than during the April-September period. This lack of use coincided with the rut; and, adult bucks probably spent more time following does than feeding (developed areas were used heavily for feeding) during this period.

All deer (except newborn fawns and yearling females) made more use of developed habitats in daytime during the April-September period than during other quarterly periods. This may have been in response to attacks by mosquitoes. During the October-March period yearling females utilized developed areas much more extensively at night than at other times. At present there seems to be no explanation for this difference.

Adult bucks, adult does, and yearling does, in both night and day periods, utilized pine habitat much less during January-March than the remainder of the year. Adult bucks spent more time in buttonwood and hardwood habitats, adult does greater time in hardwood areas, and yearling does more time in buttonwood areas. The day and night use of pine lands by adult bucks and does increased throughout the year following the January-March period.

There was a tendency for all animals to occupy hardwood areas more during daylight hours than at night. Mangrove and buttonwood areas also appeared to be utilized greater during the day. All these areas offered cool bedding and loafing areas during the day.

Dispersal

Observations and road mortalities of 223 marked animals were used to determine dispersal of animals on and off Big Pine and No Name Keys. Trips to outer keys were made to determine if an extension of the Key deer range had occurred. Transplants of deer were utilized to gain further knowledge of deer dispersal.

Dispersal of deer on Big Pine Key was difficult to determine as many deer made long "exploratory" movements. Unless the animal was tagged as a newborn fawn it was difficult to determine its "original" range. Movements of older animals may have been returns to "old" ranges and not true dispersal. Extreme movements thought caused by the drought of 1970-1971 complicated analysis of dispersal. Extension of ranges by adult bucks during the rut made it difficult in many cases to evaluate the status and occurrence of "true" dispersal.

In general, most yearling males were found to disperse from their areas of birth. Only three yearling females were known to have dispersed; however, others made long trips only to return. Adult bucks, especially during the rut, made trips to all parts of Big Pine Key, usually to return to "normal" ranges following the rut. However, some adult bucks could be several miles from these "normal" ranges at all times of the year. Two adult does moved in response to clearing of their "old" ranges for a housing development. Some

dispersal on Big Pine was believed the result of pressure due to increasing deer population levels, or due to shifts in centers of deer population activity in response to clearing of habitat in conjunction with subdivision development.

Only five sightings (one unconfirmed) of marked deer off Big Pine Key were recorded during this study. One adult doe was captured and marked on 17 June 1971 when swimming between Big Pine and Porpoise Keys. During dry weather this adult doe, which had dropped her fawn on Porpoise Key, a small island having no fresh water, swam across an 0.8-mile channel between Porpoise and Big Pine Key, the closest source of permanent fresh water. She generally moved to Big Pine around 1800 hours, stayed the night, and returned to Porpoise between 1100-1300 hours the next day. The trip was usually not made again until the evening of the following day. Trips to Big Pine were discontinued for 7 days after heavy rains but resumed when presumably pools of rain water were exhausted. Since the wind seldom was from a direction affording olfactory cues by which to orient, it was questionable how she began and maintained the proper direction to arrive at the appropriate key rather than others nearby. This doe continued these trips to Porpoise periodically until 31 July, at which time she remained on Big Pine Key. The fate of the fawn was undetermined, although Porpoise Key was searched.

Two adult does which were captured on Big Pine Key were observed on No Name Key with young fawns. One doe swam across Bogie Channel twice daily, moving to No Name in early to mid-morning and returning in late evening around dusk. Since there appeared to be adequate

acceptable water and food on No Name, no explanation was apparent as to why she repeatedly returned to Big Pine each morning. This doe was last seen on Big Pine Key in June, 1973. The second adult doe was captured in Koehn's Subdivision of Big Pine Key and stayed in south Watson Hammock during April-May of 1971. The sightings of this deer along the main road of No Name Key represented a move of about 4 miles from Watson Hammock. It is believed that she did not swim to and from Big Pine Key daily, but had moved to No Name and stayed. This deer was last seen on No Name Key in June of 1973.

One adult buck originally captured in Port Pine Heights Subdivision at the north end of Big Pine Key on 26 April 1971, and subsequently located just north of the Overseas Highway, was later found dead on No Name Key on 11 July 1971. Because the carcass was found on a trash dump, it seemed probable that this animal was a roadkill on Big Pine and had been transported and dumped on No Name. Another marked, adult buck was sighted on No Name Key twice in April, 1971; 1 week later it was observed in the Doctor's Arm Subdivision on Big Pine, and on 2 February 1973 it was a highway mortality on Big Pine Key.

There were several reports during this study from local fishing guides of deer swimming between Big Pine, No Name, and Little Pine Keys and between Big Torch and Water Keys. Several of the sightings probably involved the adult doe mentioned previously. A male fawn was captured by the investigators on 7 February 1969 while swimming between Water and Big Torch Keys.

It is of great interest that except for the deer mentioned previously no marked deer were sighted or roadkilled off Big Pine

Key. With 223 deer having been marked on Big Pine, this observation suggests doubt as to there being many deer dispersing from Big Pine. None of the 187 radio-tagged deer were ever located off Big Pine Key despite a daily monitoring of their activities. Because of the interest of residents of the Keys in the research, sightings of collar-marked deer on keys other than Big Pine would have resulted in reports if such dispersal occurred. Dispersal of deer from Big Pine Key was, therefore, considered to be very limited.

There seems to have been an extension of the Key deer range since Dickson's study of 1955. Aside from the 12 keys where Dickson either had observed deer tracks or droppings, various sign or deer were observed on Mayo, Porpoise, Water, Summerland, Sugarloaf, Treetop Hammock, Big Knockemdown, Big Munson, and Wahoo Keys, and an unnamed island southeast of Ramrod Key. Other keys visited and not found to have deer sign were Horseshoe, Crawl, Raccoon, East and West Bahia Honda, Big and Little Spanish, Content, Cutoe, all Newfound Harbor Keys except Big Munson, Loggerhead, and the Mud Keys. A deer was reported on Snipe Key and one was seen on Sugarloaf Key by Jack Watson, Refuge Manager. This was the first confirmed sighting for this key, although tracks had been seen earlier. It would appear that there has been considerable extension of the Key deer range, much of which must be considered seasonal as well as temporary in time.

In order to establish a better understanding of dispersal, seven transplants of deer from Big Pine Key were made to outlying keys. An adult male captured 6 May 1971 in Port Pine Heights Subdivision was placed on Mayo Key. Fresh water was not available

on Mayo Key and the buck returned to Big Pine Key within 4 days. This indicated that possibly the animal left either due to lack of suitable drinking water or homing instinct. In order to examine further the impact of these two factors, another adult buck was moved on 15 July 1971 from Big Pine to No Name Key, where there was fresh water and was a population second to that of Big Pine Key. Radio-contact was lost with this animal soon after transplanting; but, he was sighted on No Name 2 weeks after release. At this time he was on the west side of the Key immediately across the channel from Big Pine, after having been released on the east side. One week later an unconfirmed sighting of this animal was reported near the center of Big Pine; and, about 1 week later he was located within ½ mile of his original capture site. The results from this transplanting suggested that when Key deer were transplanted to new areas, it must be assumed that some at least will return to old ranges.

To further understand the reasons for movement of transplanted deer, the adult buck, previously released on Mayo Key, was retrapped on 20 December 1972 and released on Big Johnson Key. No acceptable water seemed available at the time of release. Within 1 week he was located on Little Pine Key were acceptable water was believed available; he was still there in early September, 1973. A yearling male, trapped on Big Pine on 26 December 1972, was released on Mayo Key where no fresh water was available. Radio failure shortly after release made it impossible to determine the fate of this animal. Two adult males were placed on No Name Key in December of 1972, where there was adequate suitable water. As of early September, 1973, both animals were still on this Key.

The transplant data indicated deer left keys without suitable water. Only one animal, the first buck released on No Name Key, returned to its original range from a key that had suitable water. Either this animal had a very strong homing tendency or was unable to find the fresh water and returned. To be considered, too, is the season of transplanting, sex, age, and experience of the animal, as well as extent of the rainfall and distribution of acceptable water.

Trips to outer keys have usually shown relatively fresh deer tracks even when acceptable water seems unavailable. This suggests considerable movement to adjacent keys with a return to the key that provided acceptable water. During the drought periods, deer on or visiting other keys either survived the drought without fresh water or returned to a key with permanent fresh water. It would appear deer utilizing Annette, Howe, Mayo, Porpoise, and the Newfound Harbor Keys obtained acceptable water on Big Pine Key during drought periods. Deer on Grassy, Little and Big Johnson, and Crawl Keys possibly commuted to Little Pine Key for suitable water when water holes on these respective keys dried up or were too brackish. Deer use of Water Key certainly required a swim to and from Big Torch Key; and, those using Wahoo, Toptree Hammock, and Big Knockemdown Keys were required to return to either Cudjoe or Summerland Keys for the nearest acceptable water.

Social Organization

Social organization of the Key deer was studied to establish such information for comparison with other races of white-tailed deer. However, of greater importance was the necessity to determine the

effects of social organization on censusing and on monitoring other aspects of the population dynamics of this deer. For example, the social structure must be known prior to evaluating mechanisms of dispersal or monitoring reproductive performance.

Records were kept on all sightings of marked or otherwise identifiable deer, noting any associations with other deer, time of day and year, and behavior. Deer observed in a group of two or more individuals responding to one another repeatedly were considered to exhibit a degree of organization. Deer that had brief encounters followed by a separation with little or no subsequent interaction were evaluated as individuals without specific social ties. Judgment based on brief sightings of deer often was based on prior knowledge of the behavior of the individuals involved. Radioed animals yielded observations during periods when deer were not normally active in open areas. Pregnant, radio-marked does were observed intensively in order to capture and mark newborn fawns to insure known family groups with which to work.

From data collected the percent of time marked deer were seen alone and with other deer was determined. To compare the Key deer to northern populations, frequencies of association were determined between marked members of a family unit. Using (1) the number of times two deer, A and B, were seen together, (2) the number of times deer A was seen alone, and (3) the number of times deer B was seen alone, the frequency of association was determined as follows (Hawkins and Klimstra 1970):

$$\text{Frequency of association} = \frac{(1)}{(1) + (2) + (3)}\ .$$

The social structure of Key deer was similar to that of the northern white-tailed deer in that adult bucks were generally solitary, forming only temporary feeding or breeding units, while other deer tended to form matriarchal family units, composed of the adult doe and her offspring of the current, and occasionally of previous, years. While the bond between a doe and her young fawn was strong, bonds between most Key deer were generally looser than the northern white-tails. While most young fawns were observed at some time with a doe, some 6-month-old fawns were never observed to be with a doe. All associations were variable depending on the individual deer involved.

Marked adult bucks were seen alone 72.6% of the time, varying from 56% in November to a high of 89% in March. Associations with other adult and yearling males averaged 17.7% but varied from 6.1% in March to 27% in June. The greater association in June and July occurred as bucks in velvet moved into open areas to feed; and, probably, to get out of thicker vegetation where insect pests were bad during the rainy season. Buck-buck associations decreased during the breeding season to around 13%. Despite their open antagonism during this period, they were often attracted to receptive females at the same time and thus were seen together. As they dropped antlers in March and were then suddenly defenseless against other bucks and aggressive does with fawns, they became more solitary. Their secretive behavior at these times compounded problems of determining actual sex ratios of the herd and estimating the population size.

Adult, fully-antlered bucks were dominant from mid-summer through February and early March, harassing most other deer that they

encountered. However, as they dropped antlers and young fawns were born, the social structure shifted so that adult females were dominant; older does were generally top in the hierarchy. Does were seen to drive adult bucks, yearlings, and strange fawns out of an area by forcefully kicking with front feet and pursuing them for 100-200 yards.

Adult does were observed 53.8% of the time alone; 24% of their time with fawns, 16.8% with yearlings, and 13.9% with other adult does. Does became somewhat solitary in March just prior to parturition, some driving out old fawns, yearlings, and adults from their area just before fawning. The primary associations between does and their fawns of the previous year were often broken during this period; this was especially true for the interaction between does and their male fawns. Female fawns showed some tendency to reassociate with their mothers as yearlings. Some does, however, separated themselves from other deer only while giving birth and then immediately reassociated with their old fawns (now yearlings). These behavioral patterns varied markedly between individuals.

Fawns spent very little time with does after their first day, then from 1 month on spent increasing time moving within the doe's range. In June and July fawns began moving in the open with does, sooner in wet years when insect pests were bad enough to drive them into the open to bed.

Young fawns associated with almost any deer that passed by; and, there was some indication that at least one 1-day-old fawn was being cared for by a strange doe other than its dam. But, most does

rejected attempts to nurse by fawns other than their own. Recognition appeared to be chiefly by scent. Adoption may possibly follow loss of a very young fawn.

During June through March male fawns were seen to be alone 54.2% of the time and females were alone 39.7% of the time. Males and females were with their own dams 48.3% and 59.1% of the time, respectively. Fawns generally associated with does until just before parturition, at which time the frequency of the association dropped sharply.

By mid-July most female yearlings had reassociated with females and sibling fawns. This was generally interrupted by the breeding season when bucks, harassing the yearlings, separated them from their does. Reassociation was often immediate and remained more or less constant until March, prior to fawning again. Often yearling bucks, themselves showing some evidence of reproductive activity but incapable of competing with larger males, were driven from or otherwise left their home areas.

Yearling bucks spent more time alone (65.1%) than yearling does (45.8%) and less time with their own dams (44.8% in males to 49.0% in females). Yearlings generally reduced time with does before and following parturition, those few bucks still with their dams often moved out of the range of the doe into new areas at this time.

Frequencies of association between known related deer belonging to 12 family groups were determined. Based on limited observations of these 31 individuals, the Key deer appeared to have lower associations than the Illinois deer with which they were compared (Hawkins and Klimstra 1970). The frequency of association during June

through March between adult does and their male and female fawns averaged 31.2 (14.5 in September to 71.2 in December) and 36.6 (21.8 in September to 61.2 in August), respectively. Yearling males and females averaged 18.7 and 20.2 with their respective does during April and July, and during the secondary associations of August through March averaged 5.8 and 27.9, respectively. In Illinois deer the fawn-doe association from September through June was 74 (72 for females and 75 for males), much higher than for Key deer.

Due to the loose association of many deer, sightings of deer with fawns cannot be used as indication of reproductive success of the adults involved; fawns are known to move with almost any deer that passes. Counting such deer may lead to overestimation of the population increment as well as level. Likewise, since does are often never seen in the open with their fawns, underestimates may result. To avoid such confusion as over- or underestimation, or misjudging the frequency of twinning or frequency at which fawns are lost, it is necessary to mark individuals of family units, capture and mark their newborn fawns, and maintain a rigid schedule of close observation of these deer.

Since social organization is so variable between deer, use of small numbers of animals can be misleading. For example, one marked doe kept two male offspring with her until the ages of 1 and 2 years. When last observed, the 2-year-old was still attempting to nurse and, when separated from his dam, moved through the woods uttering a contact call similar to that of a fawn. Generalizations based on such an observation are misleading and atypical of most behavior between does

and their male offspring. Conclusions must be arrived at with caution and only after sufficient observations on a number of deer.

Some Behavioral Patterns

An appraisal of behavior patterns and their occurrence is essential for determining times which are best for censusing and capturing deer. In addition, an understanding of aspects of behavior offers explanation of observed sex-age ratios at different times of the year.

Records were kept of all deer seen, times of observations, locations, associations with other deer, and behavior. Radio-marked deer were observed closely at various times of the day and year to better define any behavioral patterns and to understand the circumstances under which these occurred.

Deer used open, developed areas such as mowed roadsides, lawns, areas between canals in housing subdivisions, and burned areas for feeding, loafing, and escaping insect pests. Use of such openings facilitated monitoring the population and observing behavior, resulting in 12,649 observations of deer during October, 1969 through September, 1971. Two peaks occurred in use of open areas (Figure 6) with one at around 0500-0600 hours, just before and after sunrise. This was generally followed by a lull beginning around 1000 hours, when human activities increased, and extended through the hotter parts of the day to 1500-1600 hours. The second period of intensive use was around 2200-2400 hours, declining briefly around 0300 hours. In general, a few deer could always be seen using openings between 1800 and 0800 hours the next morning.

Seasonal variation occurred in the deer activities in open areas (Fig. 7). Beginning in April deer increased their use of these areas through June and July, then tapered off until September when breeding activities began. Another increase occurred at the end of the breeding season in December as deer began feeding together when antagonism decreased and bucks returned to home areas. During June, July, and August the daily times of activity shifted; deer were most active in the morning around 0700-0800 hours, and remained more active in open areas in all but the hottest parts of the afternoon. Less activity in the open occurred in late evening hours. This was most prominent during and following the heavy rains in early 1970 but was less noticeable the next year, which was much drier. It appeared that this habitat utilization was a means of escaping the large numbers of mosquitoes and deer flies that were so abundant in heavy cover. The slight breezes in open areas reduced markedly insect activity. But even in this cover type, deer bedded in such a way as to keep their legs and a portion of the face covered, reducing the most vulnerable areas to insect attack.

Recorded deer use of open areas was influenced by those times when observations were being made. However, observations occurred during random periods each day while radio-tracking animals, while deer-capturing at nights, and while driving the roads at all hours of the day in connection with behavior studies. While times of greatest deer activity were emphasized as best for deer capture, observations were made at all hours of the night. Although peaks of activity in open areas were somewhat exaggerated by when observations were made, the basic patterns of activity should be valid.

At each observation, behavior was categorized into five basic types: standing, moving, feeding, bedding, and reproduction. Marked deer were seen standing 14% of the time, moving 37.6%, feeding 34.1%, bedded 12.1%, and breeding 1.4%. Deer recorded as standing or moving frequently did so because they were disturbed as often they had terminated other types of behavior and activity in response to intruders. This behavioral pattern occurred most at night with a peak of 69.4% occurring around 0500-0600 hours. Spotlighting deer often disturbed them, especially when repeated efforts to capture were made in a given area; thus, actual behavior at the time could often not be determined. The fact that deer were more "spooky" in early morning than later in the evening hours meant that late evening hours were better for monitoring deer when identification as to sex and age of each animal was possible. Frequently deer seen in the early morning hours quickly moved to cover at the approach of an automobile; hence, sex and age were often undetermined.

Deer fed at two peak times, in early morning (0700-1100 hours) and in late evening (1400-2000 hours) (Figure 8). The hotter mid-day hours were spent bedded in thick vegetation where it was cooler; this was often at the edge of openings, in palm clumps, or palmetto-filled depressions in pine woods. Around 2100 hours intense feeding declined, only to be intensified again around 0700 hours. A number of observations were recorded of deer that did not fit this pattern; and, in some cases these were always the same animals.

Except for the 2000-2059-hour period, breeding activities were seen at all hours of the day with most intense activities around 0700 and 1600 hours. These were times when deer tended to become active

after rest periods, and when males tended to renew chases testing the does. Later they calmed and fed or slowly moved together, especially if the doe was not at the peak of estrus. Breeding activities generally paralleled times of feeding. Because breeding deer were always disturbed by spotlighting, very few observations were made after dark. Also, does were wary while being harassed by bucks, making it difficult to approach and remain with deer engaged in breeding activity in the thick vegetation.

Some differences existed between sex and age classes in times and types of behavior. Fawns were not particularly active until about 2 months of age when activity began increasing. In August and September plateaus were reached with females and males spending roughly 15-20% and 10-15% of the time bedded, respectively. Yearlings exhibited 10-15% of their time bedded while, as adults, they bedded about 5-15% of the time. The extent of such activity showed seasonal fluctuation. From birth through 2 months of age females appeared slightly more active than males, but during and after June males spent increasingly more time than females in moving around. This pattern of movement may partially account for a greater male fawn mortality.

In general, male and female yearlings spent similar amounts of time bedded, except the former bedded somewhat more in summer and less in winter. From April through August males moved less and fed more than females but this changed drastically in September, during the breeding season when yearling males were pushed from their areas by larger males. This also corresponded to the maximum time of dispersal.

Patterns of daily activity for adult males and females were similar. However, there were seasonal differences in activity patterns. Adult females bedded more during October through May and were recorded feeding more in April, June through November, January, and February, whereas adult males fed more in December and March and bedded more in June through September.

Adult males were most active in open areas during April through August with little activity in January through March. This secretive behavior in the winter and early spring accounted for bucks being seen very little in these months. It also accounted for differential mortality at different times of the year (see Mortality).

The best time to observe deer in the open is during summer months at twilight around 0500-0600 hours and between 1600 and 2000 hours. These are times when intense use of open areas overlaps with times of increased feeding activity and deer are therefore readily seen. Care must be taken in determining the sex and age composition of the herd, based on observations at any one time of the year, since differential behavior between deer of various sex and age results in changes in the ratios of deer seen. This differentiated behavior may also explain the differential mortality of deer on Big Pine Key.

SOME MORPHOLOGICAL FEATURES

Body Size and Color

Based on analysis of roadkilled deer for January, 1968 through March, 1971, and on weights taken on captured live deer from 1968 through June, 1973, the following generalizations seem valid. Males grew at a faster rate relative to females and showed more variability, the most variable group being male fawns.

At birth fawns weighed 2.2 to 4.5 pounds, with a mean of 3.8 pounds for six fawns ranging up to 6 hours of age. One doe fawn weighing 3 pounds at birth tripled her weight by 2 weeks and was 5 times heavier (17 pounds) by the end of 7 weeks. A male fawn weighing about 3 pounds at birth had doubled his weight after 2 weeks, weighing 6.6 pounds. Males attained 40.3% of the average maximum total weight during the first 12 months, while in the same period females attained 33.3% of the average maximum total weight. The average weight of bucks captured was 42.5 pounds at 1 year, 59.7 pounds at 2 years, and 79.8 pounds for all males over 2 years of age (Figure 9). All females captured had average weights of 37.0 pounds at 1 year, 54.9 pounds at 2 years, and 63.2 pounds for all over 2 years (Figure 10). Maximum weight for does was reached at 54-57 months, whereas bucks continued to gain throughout their life. The heaviest buck was roadkilled on Little Torch Key in August, 1971, and weighed 137 pounds. The heaviest doe weighed 90 pounds. Does tended to be heavier in January, February, and March, just before dropping fawns, and least heavy in July, August, and September after nursing fawns. Bucks did not consistently show these periodic fluctuations in body weight.

There was considerable individual variation in weight of deer at any given age. This may be due in part to the extended period of fawn drop from March to late summer or fall, which resulted in various-sized fawns being present at any one time. On 1 April all animals considered as yearlings actually included various-sized deer of ages ranging from 6 to 13 months.

Color and size of the animals was also variable. The coat color of Key deer varied from a deep reddish-brown to a grizzled, nearly gray color. Deer of various coloration were seen at all seasons. This variability may be a result of differential exposure to sunlight or salt for deer living in different habitat types, or may be a reflection of genetic variability. Two adult deer in an observation pen were of different colors, the male being grizzled in appearance, while the adult doe was a darker brown. Very dark, large deer were jumped on Big Johnson Key. Isolation between island complexes may serve to maintain such differences between deer living on different islands. Groups of deer on Big Pine in certain areas appeared smaller than other deer, and most likely represent closely related animals. These differences most likely reflect a broad genetic front, possibly a result of breeding pockets of deer on the widely-separated island complexes.

External measurements of roadkilled deer, as well as weights of body organs, were compiled and have been reported previously (see Key Deer Investigations Progress Reports). Males tended to show greater total and dressed weights while females had greater visceral weights. In general it appeared that whereas males exhibited significantly greater tail lengths, neck circumferences, and hoof

dimensions, they were not significantly heavier, longer, or taller than females, even though there was a trend for them to have larger values for these measurements. The large variance among individuals resulted in observed differences not proving to be significant.

The ratio of height at shoulder to total length was very stable with age, was similar for each sex, and averaged 1.50 for the road-killed sample population. The ratio of hindfoot length to height at the shoulder was also stable with age, and varied from 0.65 to 0.41 within the sample population.

The weight of stomach contents at the time of death changed significantly over time. The 0400-0800-hour and 1600-2000-hour time periods showed larger values for the ratio of stomach content weight to total weight. These periods corresponded to times of maximum and near-maximum feeding periods.

Based on analysis of body weights, the relative condition of the Key deer population deteriorated in 1970 relative to 1969. This may be a result of a large number of roadkills in 1969, bias of sample by age and sex categories, or may be associated with such environmental factors as availability of food and water. Similar analysis of 1971-1973 data is necessary before statements can be made regarding the recovery of the population, if any occurred.

Antler Characteristics

Key deer lost their antlers during February and March, most bucks having shed them by April. Regrowth began almost immediately and by June bucks with 2-inch stubs were seen. Growth was completed by August and velvet was rubbed and kicked off in early September.

Based on observations in the field and on statistical analysis of bucks roadkilled during January, 1968 through March, 1971, the following conclusions regarding antler development may be made. Fawn males which produced buttons their first year often remained in velvet until January, and polished only just before losing the buttons. During their second year they produced 1-2-inch spikes. On the average, the first fork was attained at the approximate age of 23 months, the second developing at 2½ years. Bucks generally developed six points at 45 months and did not develop eight points until the age of 5 years. That this slow rate of antler development may be a reflection of some aspect of the diet was suggested when a captive buck produced a six-point rack at 2 years of age and consistently produced large racks each year thereafter. Several apparently abnormal antler formations were seen each year; spurs occasionally occurred on the outside of the beam, deer had long unforked spikes, and one adult buck consistently lost his left antler just after shedding the velvet. These may have resulted from injuries sustained while in velvet.

Skull Characteristics

A comparison of selected cranial measurements for *Odocoileus virginianus clavium* and *O. v. borealis* was made based on 50 skulls of the former and 72 of the latter. Twenty selected measurements were made for each skull. In adult males the range of *borealis* measurements, based upon length of a bone in the skull, or the skull, was distinctive from *clavium*. Completely distinctive measurements regarding the length of the *clavium* skull indicated a shorter length (than *borealis*) without corresponding reduction in width. In all

age and sex classes for which tooth row lengths were compared between clavium and borealis this was the most distinctive measurement, clavium being the shorter (Table 15). This also seems apparent when compared to other studies on borealis except for that of Phillips (1920), with which there appears to be overlap. These borealis measurements may have included skulls with missing teeth or may have involved different measurements. There are clear distinctions between tooth row measurements of clavium and O. v. osceola and O. v. virginianus, both of which are also found in Florida.

Only in the case of borealis and clavium fawns were there less significant differences in measurements. Most interesting was the lack of clear differences in length and width of the skull, suggesting a change in proportions with increase in age in clavium. Approximately 40% of adult skulls examined showed the loss of the first premolar on one or both jaws; milk teeth of fawns did not show this.

Age Characteristics

Use of tooth eruption and wear criteria as described by Severinghaus (1949) was used to estimate the age of Key deer. However, the validity of this technique as well as lens weight and dental cementum layering are questionable, at best. There is no assurance that the schedule of tooth eruption and replacement established for northern white-tails (O. v. borealis) applies to Key deer. Some animals, obviously yearlings or less, showed heavy tartar deposition; a surprising number of adult skulls did not show full sets of teeth. Of 50 adult male and female skulls examined, 20 (40%) did not show a permanent first premolar on the lower molariform tooth row; 9 (18%) showed the reduction on both lower jaws.

Following the procedure outlined by Ludwig (1967) for using wet and dry lens weights as an age determination technique, a total of 67 Key deer lenses were processed. The dry weights were graphed against age classes (estimations based on teeth) by ½-year intervals (Figure 11). There was a positive correlation between increased age and increased weight of lenses in Key deer.

Use of tooth sectioning has proved unproductive to date. While growth rings were found in _O. v. borealis_ teeth used for comparison, the slight indications of cementum layering at the junction of the molar root and periosteum in _O. v. clavium_ teeth could not be related to age.

Throughout the study ageing was based on tooth replacement and wear, despite the inconsistencies with this method. Until successful methods of sectioning Key deer teeth are devised, and until animals which have been captured at known ages during the study die and are examined, techniques of accurately ageing deer over 2 years old cannot be developed.

Blood Protein Characteristics

As a part of the total effort to establish the precise identity of the Key deer race, analyses of blood serum were conducted using paper electrophoresis. Seventy-five blood samples of _O. v. clavium_ collected from fawn, yearling, and adult age classes, during all seasons of the year, were compared to 60 samples of blood from the _O. v. borealis_ race from Crab Orchard National Wildlife Refuge in Illinois. Four similar proteins were found in both groups of deer; however, the proportions of each protein varied so much that no significant differences were revealed between these two populations.

One problem is that serum proteins are capable of rapid change with stress, plane of nutrition, season, age, reproductive state, and physiological condition (Youatt et al. 1965, Van Tets and Cowan 1966, Bandy et al. 1957, and Teeri et al. 1958). For this reason paper electrophoresis studies of blood serum should only be used in conjunction with other taxonomic tools to establish the status of the races of white-tailed deer.

Parasites

All live deer handled were examined for external parasites. Fecal samples and blood smears were collected and examined for internal parasites. Dead deer were checked for external parasites and ears were saved or scrapings made. Additionally, fecal samples were saved and body organs frozen for later examination. Analysis of 27 ear scrapings disclosed 13 ticks, *Ixodes scapularis*. Key deer appeared relatively free of ectoparasites except for ticks, mosquitoes, and deer flies. Twelve blood smears and preliminary analyses of eight body organs have not revealed the presence of internal parasites.

Fecal samples from captured Key deer and from fresh roadkills were preserved in 10% formalin. Two methods were employed in fecal examinations, initially a modified Sheather's Sugar Flotation Technique (Benbrook and Sloss 1961) was used; this was followed by the modified Fluke Egg Technique (Benbrook and Sloss 1961). From 100 samples collected from 88 Key deer, three genera of nematodes, one genus of coccidian protozoan, and one genus of trematode were found. The nematodes recorded were *Oesophagostomum*, *Neoascaris*,

and *Gongylonema*; the trematode was *Dicrocoelium*, and the protozoan was *Eimeria*. All but *Neoascaris*, which may produce verminous pneumonia and hemorrhages in cattle (Morgan and Hawkins 1949), have been previously reported in white-tailed deer. There was no indication that these intestinal parasites occurred in sufficient quantities to produce pathogenic effects.

SOME DIETARY ASPECTS

Observed Food Habits

From December, 1969 through December, 1972, line transects were run at 3-month intervals in the five major plant communities within the Key Deer National Wildlife Refuge on Big Pine Key. In addition, open areas of subdivision developments and right-of-ways; recent cleared and/or burned areas, firetrails, and mosquito ditches; and open areas resulting from prior (several years) land use activities within hardwood-hammock habitats were similarly examined but in a less organized manner. To further evaluate the impact of deer feeding, nine exclosures were established in red mangrove, pine woods, grassland, mixed hardwood, and openings in hammocks. Also, frequent visits to other keys provided an opportunity to record additional deer feeding activities. A generalization of these observations and of the recorded data follows:

1. Changes in food utilization were clearly associated with different seasons, which probably reflected availability but also predilection and "nutritional" need of the deer.
2. A few plants were usually subjected to regular and continuous browsing, wherever they occurred, to the extent that some were stunted while others were nearly absent except where protected or out of the reach of deer.
3. Following fire in pine lands, new woody and herbaceous plant growth immediately attracted deer and extensive browsing occurred for up to 6-9 months. Use then declined rapidly, and as previously observed by Refuge personnel deer use was drastically reduced by about 18 months.

4. Following fire in open, grassy areas, new growth of certain species was heavily browsed to the extent that a few species, largely herbaceous, did not become established as a part of the grassland community.
5. Foods utilized by deer varied considerably from one area of a key to another and particularly from one key to another. This utilization was in some cases due to availability; but, some differences in preferences from area to area, for which there was no clear explanation, were clearly indicated.
6. Although open areas such as roadways, subdivisions, and clearings held an attraction for deer for a variety of reasons, herbaceous, woody, and grassy plants of such sites were regularly browsed, especially when periodic mowing was a part of maintenance practices.
7. With regard to exclosures, only in conjunction with those located in openings in Watson Hammock and the burned grassy areas at the north end of Big Pine Key was there ready evidence of browsing.
8. Use of certain plants or plant parts (i.e. grasses, fruits, and flowers), unless an animal was seen feeding, was such that ready evidence of deer use was virtually impossible to record by way of "sign".
9. Virtually no plant species, or part thereof, was immune from deer use at one time or another.
10. During a feeding period a given deer might concentrate on as few as one species or as many as 35-40, depending on type of habitat and season.

11. Because of the extent of movements and the general activity, a given deer probably utilized a wide variety of plant species, even in a short period of time.

It was possible to establish "indicator species" for most plant communities. However, because of the extent and time of deer browsing, the parts of the plant utilized, the stage of plant succession, the nature of man's disturbance, and the accessibility of certain species to deer for browsing, a complete and critical analysis was not permitted. Herbaceous species, especially low growing forms (i.e. _Melanthera parvifolia_; _Borreria terminalis_; three-seeded mercury, _Acalypha chamaedrifolia_; creeping morning glory, _Evolvolus grisebachii_) and invaders (i.e. creeping morning glory, _Evolvolus alsinoides_; bladder mallow, _Herissantia crispa_) early in successional stages, were often absent (or nearly so) from given plant communities. Also, some species (snowberry, _Chiococca alba_; devil's claw, _Pisonia aculeata_; poison ivy, _Toxicodendron radicans_) were limited in occurrence, being sparse and irregular in their distribution. Because of growth forms characteristic of certain plant communities (hammock and hardwood), most plant parts were sparse and usually inaccessible to the deer. But, in such areas, openings showed not only a contrast in types of plants but also concentrated deer use at certain times of the year, including extensive browsing as well as bedding and trampling. Areas with accumulated organic matter (pine-palm and grass areas) yielded little browse (both herbaceous and woody) at the ground level; however, in contrast, following disturbance or burning

extensive variety and quantity were exhibited in the available browse. Clearly, certain plants contributed flowers, fruits, and leaves extensively used by deer; but, only in the case of consumption of vegetative parts could there be a reasonably confident appraisal of the extent of deer browsing. The subtle use of flowers and fruits often defied appropriate analysis of the degree of such use on a given plant. Fruit utilization was further complicated by the fact that several birds and mammals, especially raccoon, were competitors with the deer. Only with an analysis of stomach contents and pellets will a more accurate and complete understanding become available. The above, as well as a variety of other factors, influenced the selection of indicator species and may well have directed inaccurate summations. However, of the woody species, wherever snowberry, joewood (*Jacquinia keyensis*), white indigo berry (*Randia aculeata*), devil's claw, poison ivy, limburger (*Morinda royoc*), catbrier (*Similax havanensis*) and blolly (*Pisonia discolor*) occurred within the Key deer range, there was a prominent browse line or plants were so extensively browsed as to be stunted in their development. In addition, a listing of representative plants which showed each to have been browsed 50% or more includes ground cherry (*Physalis augustifolia*), blazing star (*Liatris tennifolia*), beggar tick (*Bidens pilosa*), capeweed (*Lippia nodiflora*), hemp vine (*Mikania batatifolia*), *Melanthera*, false foxglove (*Agalinis* spp.), three-seeded mercury, *Borreria*, snowberry (*Chiococca pinetorum*), saffron plum (Bumelia celastrina), creeping morning glory, *Erithalis fruiticosa*, Christmas berry (*Crossopetalum ilicifolium*),

nightshade (Solanum blodgettii), vine milkweeds (Cynanchum spp.), white vine (Sarcostemma clausa), Eustoma exaltatum, mallows (Malvaceae), and saw palmetto (Serenoa repens) (flowers).

The degree of browsing pressure as recorded by observations, exclosures, and line transects does not appear to have changed significantly since 1969. Although there are individual sites and plants which continuously show the same level of deer use, the major segment of the Key deer range has not been subjected to overbrowsing. Clearly, land use activities such as mosquito ditching, clearing, roadways and right-of-way management, subdivision development and management, firetrails, burning, etc. have at periodic intervals affected food availability. Generally, the early stages of plant succession resulting from these activities, the "edge effect" created by breaks in the continuity of uniform plant communities, and the resulting increased diversification of plant communities have yielded an increase in the availability of potential deer foods for a limited period and in selected areas of the Key Deer Refuge. Such activities also directed to no small degree the movements of deer as well as to the localization of deer activities.

To be analyzed are over 100 samples of stomach contents available from various mortalities, largely roadkills. These will assist in validating field observations as well as complete the understanding of plant utilization. Most importantly, it will provide an overview of fruit consumption not fully appreciated from sign of browsing.

Caloric Values of Potential Foods

Energy values were determined for 312 samples of 87 species of plants, employing a Parr oxygen bomb calorimeter to run standard calorimetric analyses. Plants sampled were those available to Key deer on Big Pine Key; included were various plant parts collected during different seasons. Complete plant lists and their corresponding caloric values are reported in Key Deer Investigations Annual Report for 1969-1970.

Energy values in calories per gram ranged from a low of 1985 for saltwort (*Batis maritima*) to a high of 5940 for bustic willow (*Dipholis salicifolia*). Generally the fleshy, salt-tolerant species were very low-ranking; very few yielded over 3,000 cal/g. Of plants known to be utilized by the deer, the mean for the samples was 4534 cal/g. *Erithalis*, dilly (*Manilkara bohamensis*), joewood, and Key thatch palm (*Thrinax microcarpa*) yielded values of 5100 cal/g or more. Only one sample of white mangrove leaves had less than 4000 cal/g. Little variations occurred between energy values of certain plant parts sampled; but, seasonal variations were found in the same part of a plant sampled over time. It appears that many foods available to and utilized by the Key deer on Big Pine Key are equivalent in energy content to various commercial animal feeds. However, the full appreciation of nutritional levels for plants used by deer awaits several other types of analyses.

Water Availability and Utilization

Water requirements of various ungulates are reported in Key Deer Investigations Progress Report 16 (1972:10-18). A total of 192 water samples from potential Key deer watering sites on 11 islands was collected during January, 1970 - June, 1971. Potential watering sites included natural ponds, the heads of mosquito ditches, and surface depressions. In general, samples did not include water from mosquito ditches themselves or that which had obviously accumulated as a result of tidal action. Although an attempt was made to sample all areas, the majority of samples collected from Big Pine Key were along a prescribed route which encompassed most of the northern half of the island. Sampling from other keys usually coincided with an intensive search for deer sign. In many cases samples were collected from the same source at different times during the 18-month collection period.

Water samples were anlayzed for solute content by means of an Osmette A osmometer. The mean osmolality and equivalent percent NaCl of water samples are listed in Table 16. In general the water samples analyzed displayed a markedly greater solute content than those reported by Dickson (1955:11). In part, this may be attributed to the fact that the area experienced drought conditions during November, 1970 - April, 1971. However, the results were probably more greatly influenced by the fact that Dickson repeatedly sampled selected sources, whereas samples herein reported were collected from any potential watering site. Figure 12 shows the percentage distribution, according to equivalent percent NaCl, of all water samples, samples from Big Pine Key, and those from all other keys.

Of all samples, 37.5% had an osmolality less than that of 0.5% NaCl. Forty-four percent of the samples from Big Pine Key fell into this category, as compared to only 29% of the samples collected from all other keys. This difference is reflected by the small, but consistent, trend for the samples from other keys to be disproportionately represented in the categories of higher solute concentration.

At present there is no published information pertaining to the salt tolerance of American deer. The data of Peirce (1957, 1959) indicate that sheep can utilize 1.3% NaCl, but that higher concentrations have adverse effects. Weeth and Haverland (1961) found that NaCl solutions greater than 1.0% had detrimental effects on cattle. During March-September, 1971, experiments were conducted on four yearling Key deer to evaluate their tolerance to NaCl solutions. Because of the large number of variables monitored and the rigorous chemical analyses being employed, data analysis is incomplete. However, based on changes in body weight and food consumption, it is evident that the Key deer's salt tolerance is at least as great as that of sheep.

In relation to information on salt tolerance, it is probable that the availability of water with a salinity less than 1.5% is of biological importance. Only 53% of the water samples collected from other keys had a salinity less than 1.5% NaCl, as compared to 72% of the Big Pine samples. This difference, together with Dickson's observation (1955:10) that salinity varied inversely with rainfall and the recent information that habitat utilization by

mule deer was related to the availability of permanent water sources (Wood et al. 1970:21), suggested that the distribution of Key deer may be influenced by extremes in rainfall.

Rainfall at Key West (30 miles west of Big Pine Key) was likely to be indicative of trends in rainfall at Big Pine and surrounding keys. The long-term average at Key West was 101.6cm annually; however, it must be appreciated that rain rapidly seeped through cracks and holes in the surface rock (oolitic limestone) and accumulated in inaccessible solution holes. Also, most rain which collected on the surface was available only for a period of days, since evaporation was rapid and surface depressions were generally shallow. Rainfall was normally greater than 10cm per month from June-October (Table 17); during this period fresh drinking water was probably readily available. The driest period normally occurred from December-March when a mean of 4.4cm per month was received. Even if this amount of precipitation occurred, it was likely that during these months drinking water became both scarce and saline. During the December-March period observed by Dickson (1955:17), precipitation on Big Pine Key averaged 3.2cm per month, yet the salinity of some water holes increased by factors of 5-15.

Another characteristic of precipitation in the Keys was its spatial variability. During a given rain it was common for the north end of Big Pine to receive heavy rain, while the southern half received little or none. Records from Key West have been utilized primarily because data for Big Pine Key were incomplete;

although the major trends were similar, some notable quantitative differences existed. For instance, during the drought of November, 1970 - April, 1971, Key West received 9.9cm precipitation while Big Pine Key received only 5.3cm. It was likely that this degree of variability existed among other islands.

Quarterly rainfall fluctuations were compared with quarterly Schumacher-Eschmeyer population estimates for the portion of Big Pine Key covered by the 10-mile weekly road census (Fig. 13). Fawns were only included in population estimates during the first and fourth quarters of each year because they were rarely observed at night during other periods. Thus, the quarterly deer estimate does not represent the actual sequence of population changes because quarters two and three would have lower estimates. This bias, due to a tendency for annual peaks in the population estimates to be associated with the annual period of low rainfall, could be eliminated by expressing rainfall as a percentage of the normal quarterly precipitation (Fig. 14). The interval encompassed by the first quarters of 1969 and 1970 was one of high rainfall, both in absolute and relative terms (Figs. 13,14). During this time the censused population showed little evidence of increase. In January-March, 1969, the population was estimated at 61 animals, as compared to 67 deer 1 year later.

During the second quarter of 1970, rainfall decreased to 12.0cm, only 51% of normal. The population estimate for this period was 98 deer, as compared to the previous quarterly estimate of 67. Unless immigration occurred, the April-June estimate would be expected to closely approximate that of the previous quarter,

since the same animals were included in the two estimates (fawns of Qtr. 1 become yearlings in Qtr. 2).

Coincident with the drought of November, 1970 - April, 1971, the censused population increased sharply to an estimated 156 deer in January-March, 1971. As quarterly rainfall subsequently increased, the censused population decreased to an estimated 96 deer in July-September, 1971. A decrease in numbers might be expected as a result of mortality, but it seems unlikely that the loss of 60 animals amounting to 38% of the January-March, 1971 estimate could be attributed solely to mortality.

During the fourth quarter of 1971 and the first quarter of 1972 the population estimates showed an increase of approximately 20 deer, probably because fawns were included in these estimates. During April-June, 1972 the population was estimated at 96 deer, a value identical to that of July-September, 1971.

Although it seemed apparent that the increase which occurred during the drought could not be attributed to reproduction, this aspect was investigated more critically. The population size and herd composition was estimated for a specific time, reproduction and mortality were considered, and the increase in population size was determined at yearly intervals. Schumacher-Eschmeyer estimates for total deer and sex-age classes during April-June, 1969 and for the year October, 1968 - September, 1969 were determined (Table 18). Due to a large standard error, the April-June estimate for yearling females cannot be confidently utilized; however, the close similarity across categories between the quarterly and yearly estimates

indicates that the latter may be justifiably utilized. Estimates for the four sex-age classes totaled 51 deer, but it was considered desirable to frame the initial numbers within the original April-June estimate of 70 animals. Therefore, each class has been proportionately increased as indicated in the column of revised numbers.

The age composition of the adult sex classes was estimated from roadkill data on Big Pine Key during the period April, 1969 - June, 1972. Mortalities after 1969 were assigned an age as of April-June, 1969. From these figures the percentage of each age class for each adult sex class was determined. These percentages were then used to estimate the number of adult males or females of a given age in April-June, 1969 (Table 18).

Survivorship data was determined for 110 marked deer of known fate (Table 10). It was assumed that each adult female produced an average of 1.1 fetuses and there was no fawn mortality associated with parturition. Fifty-eight percent of the fawns were assumed to be males. The results of this analysis are summarized in Table 19. In 1970, reproduction accounted for only 40% of the gain as measured by population estimates from the 10-mile road census. In 1971, only 51% of the 47-deer increase could be attributed to reproduction. In contrast, because of the decrease which occurred in late 1971, the calculated values for 1972 were greater than the census estimate. The calculated values (Table 19) should not be interpreted as a realistic estimate of potential for increase between 1969 and 1972; due to a number of factors they are best regarded as

generous overestimates. Nevertheless, the figures are of interest because they clearly do not explain the behavior of the censused population.

The interpretation of these data is that during periods of exceptionally low rainfall, deer which formerly occupied other keys were forced by lack of suitable drinking water to emigrate. Many of these animals apparently found their way to Big Pine Key which, because of its abundant watering sites with relatively low salinity, provided adequate water. Subsequent to the drought some of these animals left Big Pine Key. Other feasible explanations are that during the drought animals from other areas of Big Pine moved to the censused area and increased activity of deer from remote areas of the Key resulted in a higher ratio of unmarked deer seen. These would both serve to increase estimates. The capture of large numbers of deer during the drought period may have led to more accurate population estimates than previous estimates based on fewer marked animals.

Several isolated observations support the hypothesis that drinking water may limit deer utilization of the outer keys. Subsequent to the extremely dry first quarter in 1971, two deer skeletons were found on Howe Key and one was discovered on Big Johnson Key. These were located near dry or saline water holes which suggests that the animals were victims of the drought. During the same period, a radio-tagged doe with a fawn on Porpoise Key was observed to make daily trips to Big Pine Key. A thorough search of Porpoise Key revealed no available water. The trips to Big Pine were

discontinued for seven days after heavy rainfall, but were again resumed due to the evaporation of standing rainfall.

The lack of a significant trend toward increase during 1969 and early 1970 was also of interest since it may suggest dispersal from Big Pine when conditions on the outer keys were suitable. In this regard, precipitation was also abnormally high throughout 1968 (Table 17) especially regarding the normally dry first quarter and the fawning season (second quarter). Certainly factors promoting dispersal from Big Pine were indicated by the decline in population subsequent to the drought. As utilization of Big Pine Key by man increases, these factors are likely to become more intense. The importance of the island as a potential refuge during drought, however, is unlikely to change. As habitat continues to decrease, future droughts may promote over-utilization of remaining resources.

HABITAT CHANGE

As of 1 January 1969, major vegetation cover types of Big Pine Key (about 5,800 acres) revealed approximately 1,060 (18%) in subdivisions, 223 acres (4%) in hammock vegetation, 1,586 acres (28%) in buttonwood-scrub mangrove, 579 acres (10%) of dense mangrove, 742 acres (13%) in hardwoods, and 1,584 acres (27%) in pine woods. Around 3,000 acres of the total were within the boundary of the Key Deer National Wildlife Refuge. Of the total acreage of major cover types, about 48% of the developed lands, 62% of the hammock, 58% of the buttonwood-scrub mangrove, 48% of the dense mangrove, 21% of the hardwoods, and 60% of the pineland occur within the boundary of the Refuge. In addition to the 1,060 acres of developed lands for housing subdivisions, 60.3 miles of roads, 16.8 miles of fire lanes, and 18.0 miles of canals occurred on Big Pine Key as of 1 January 1969. These reflect 146 acres of land in roads (46% in the Refuge), 31 acres in fire lanes (75% in the Refuge), and 87 acres in canals (64% in the Refuge).

Since 1 January 1969 and through 30 June 1973, 366 acres have been cleared on Big Pine Key in the interest of residential development. Of this, 11 acres (22%) were cleared in the Refuge. Over 20 miles (49.3 acres) of roads have been constructed on Big Pine Key (23% within the Refuge) during this period. Two and one-half miles (3.1 acres) of new canals have been dug on Big Pine Key (49% within the Refuge). A total of 1,617 acres was cleared prior to 1 January 1969 on Big Pine Key; but, since that time and through 30 January 1973, 517 acres have been cleared giving a total of 2,134 acres. This represents 37% of the total area of Big Pine Key.

During the last four and one-half years land clearing on Big Pine Key has averaged about 115 acres per year. Of the remaining acres of undeveloped land, approximately 1,500 are owned by the National Audubon Society and the U.S. Government. If the above rate of development continues unchecked all remaining non-developed, privately-owned land will be developed in less than 20 years. There is now no reason to doubt that development will continue to increase as it has over the last 4½ years. The Key deer population, therefore, can only decrease due to conflicts with human populations and reduction in habitat.

MANAGEMENT RECOMMENDATIONS

Techniques of managing a resource are largely determined by the purpose of management and the resource being managed. Managing a species to maintain an unnatural population level with the idea of either providing a large harvestable resource, or controlling the species at a low level, requires different techniques than managing a population to maintain natural numbers. Inherent in any management program must be a thorough understanding of the principles which pertain to the biology of the species. This is especially critical in a program that affects an endangered species.

Prior to managing endangered plants or animals, those factors which resulted in the species becoming reduced in numbers to the point of near extinction must be understood. These then must be properly rationalized when formulating plans to manipulate the species' habitat. This is important not only to maintain population levels adequate to insure propagation of the species, but also to retain its unique integrity; in this case a subspecies (race).

The Florida Key deer, an endangered mammal, is in an especially precarious situation in that this miniature race of the white-tailed deer is the product of a very restrictive insular environment. In response to the rigorous, limited habitat of the islands, it has evolved unique characteristics. Under pressure from intense hunting, hurricanes, and habitat destruction due to farming and residential developments, the deer decreased in numbers to less than an estimated 50 animals by 1949 (USF&W Narrative Reports 1939-1967). Since being afforded protection the Key deer population

has increased to around 350 animals, about two-thirds of which are on Big Pine Key, which, historically, has been the main island for the population (Barbour and Allen 1922). It appears that on Big Pine, at least, the population has approached stability. This seems apparent as the fetal sex ratio appears to be 1 female to 1.45 males, while the sex ratio of adults observed is about 1 female to 0.42 males. The number of fetuses per adult female 2 years and older is 1.08 to 1. Similar trends are noted in stable as well as in large populations on poor range (Gunvalson et al. 1952). In effect, large numbers of fetal males provide the surplus for mortality and dispersal, and yet provide for lower reproductive potential. Adult females displaying low rates of reproduction also suggest population stabilization.

Simply an increase in numbers (such as 50 to 350) of an endangered population cannot be interpreted as being saved from extinction. The fate of any animal, especially the Key deer, is directly related to those factors which effect changes in the habitat of which it is a product.

In recent years there has been increased tourism, development and associated habitat changes due to the influx of humans in to the Florida Keys. A study released in 1970 (Milo Smith & Associates, Inc., et al. 1970) indicated that in 1964, 233,309 tourists visited the Keys; the prediction for 1980 is 1,075,000. The estimated island population for 1990 (110,340) reflects an increase of 48%. A prediction of $336 million to be spent by tourists in 1980, as compared to the $83.4 million spent in 1968, implies greater

construction of businesses, residences, and public facilities for recreation to accommodate tourists; and principally at the expense of the Key deer habitat. This surely suggests increased automobile traffic and more deer mortalities as well as hazards to humans. Also, there will be intensified conflicts between man and a deer that feeds on newly introduced plant species of yards and gardens. Not only may new plants change the diet sufficiently to cause changes in the "integrity" of the deer, but introduction of exotic animals as pets or domestics may result in accidental introduction of parasites or disease organisms for which these deer may have no defense. Exotics may also compete with the deer and other native animals for available food and cover.

It must be clearly understood that in the Florida Keys it is the habitat that is currently endangered; but as the habitat changes, so may the deer and other native wildlife. The long-term effects of these changes must be considered; and, management to insure the future existence of the deer must be planned now to provide adequate and acceptable habitat in the future.

The glib prescription for preservation of endangered animals which suggests zoological gardens or transplanting to other areas fails to appreciate that, in the case of the Key deer at least, the nature of the native environment determined the evolution of the race. By simply removing the deer from the Keys and placing it in a different environment with different diets and under new selection pressures a Key deer no longer exists. In fact, deer on keys now accessible by road may already have begun to change, due to changes in those aspects of their environment that

influence their evolution. The main cause of mortality of adult deer on islands crossed by the Overseas Highway is the automobile. In a sense the automobile is assuming the role of a predator; yet, this ungulate unquestionably evolved, within the limitations of its habitat, a mechanism of population control that did not include natural predators. Clearing of new areas and mowing roadside areas provides an artificial, year-round, probably enriched source of food. During the past few years, Key deer appear to have become larger, possibly in response to their changed diet. Change in diet seems the answer to different antler characteristics of a confined male on commercial foods.

Although the Key deer shows some distinction beyond simply a race, it surely is vulnerable to genetic contamination with other races of white-tails, should they come into contact. It is likely that only those semi-isolated deer on outlying islands may still be subjected to the pressures of natural selection characteristic of the Keys.

Within the next few years deer will be restricted largely to those government-owned refuge lands on Big Pine Key and Big Torch Key, or to the nearby outlying islands affording suitable habitat (Figure 3). It is likely that certain of these government-owned island complexes, not readily accessible to man, will be the chief refuge of Key deer in future years.

Management for these deer should involve only minimal manipulation and disturbance to the habitat, while providing suitable area in which they can thrive and maintain their integrity. The

result may be a relatively low number of Key deer. Emphasis must be on management for the unique quality of the race, not for a large quantity of animals. Some areas should have no management; others just enough to insure adequate water and proper food and cover to maintain the herd. Too much management may be just as detrimental as no management. To maintain their integrity, management must optimize the natural selective processes under which the deer evolved, and insure a natural balance among all the native species of plants and animals, such as the white-crowned pigeon, raccoon, eagle, marsh rabbit, box turtle, tree snail, and the many shore birds.

Due to the unique flora and fauna of the Keys, it is not advisable to effect widespread untested practices of management which could have destructive results to entire island ecosystems. For this reason, it is suggested that management, which should be restricted only to the government-owned lands, be conducted in two phases. The first phase, to be implemented immediately, would involve experimental manipulation of an island complex subject to minimal human influence. Such a suitable group of islands, comprising the Little Pine Key complex, are Big and Little Johnson Keys, Little Grassy Key, and Little Pine Key, which, as Dickson (1955) suggested, may serve as the future center of the deer population (Figure 3). Manipulation should be restricted to improving permanent fresh water holes and reestablishing the native pinewoods that were damaged by severe fire. Such limited management should be accompanied by close monitoring of the habitat on these

four islands to evaluate the effects of year-round use by the deer.

To prevent deer damage to private property, another short-term practice would be to restrict deer to refuge lands by establishing an experimental fenced area around a housing development on Big Pine which receives heavy deer utilization. The effects on the deer and the effectiveness of fencing as a management tool in the Keys should be noted. Long-range management involves, in most cases, a continuation of those short-range practices that proved successful in maintaining deer habitat on the Little Pine complex. After evaluating the results of these practices, similar manipulation should be considered for the Big Torch Key complex, which includes part of Big Torch, Water, and a section on Middle Torch Keys, and the Big Pine Key complex, which includes a section of Big Pine, Howe, Annette, Mayo, and Cutoe Keys (Figure 3).

Such development of refuge lands, fencing sections on Big Pine Key and Big Torch Key if feasible, and extensive habitat manipulation on government land should be implemented only in response to specific problems resulting from increased deer on the highways that present a hazard to human life, and from deer that cause increased damage to private property. Finally, while it is important to consider the human element in management proposals, especially since the Keys will serve as an important residential and tourist center in the future, primary consideration must be toward maintaining the Key deer and other fauna and flora of the Keys as unique species and as unique environmental units.

Protection

Although protection from illegal hunting on refuge lands must continue, other protection must be provided with caution, as over-protection may be as harmful as no protection at all. Natural mortality factors must be operative in order to maintain the integrity of the deer and hopefully allow intrinsic control mechanisms to operate.

Regular patrol of Big Pine and Big Torch Keys and adjacent islands accessible by automobile should be continued. The main emphasis should be in patrolling those islands which will serve as deer concentration areas in the future, with less emphasis on those islands from which deer will be exterminated as the human population grows. This provides the most efficient means of adequately protecting government-owned refuge land and yet is less expensive and time consuming.

Refuge-owned islands which are inaccessible by automobile should be patrolled regularly by boat, especially those refuge keys being experimentally managed for deer. In order to monitor the responses of deer populations to experimental manipulation, the Little Pine Key complex must be free from hunting and other human interference. Hunting could so alter the population numbers and structure that the responses to habitat improvement may be misinterpreted and, should future management practices be based on erroneous results, the outcome could be disastrous.

Deer should be protected from dogs and other introduced species on refuge lands. Although it seems unlikely that dogs

could overcome a healthy adult animal, fawns would be easy prey during the first few weeks after birth. Due to the uniquely close association of refuge and human population centers, the problem of free ranging dogs on the refuge can only increase as the human population increases. Passage of leash laws in the Keys should be encouraged and laws should be passed which prohibit dogs running loose on the refuge, or which allow for removal of those dogs that consistently harass deer. Fencing to exclude dogs and confine deer to the refuge could relieve this situation in problem areas (see Fencing).

Restricting the introduction of exotic plants and animals into the Keys must be encouraged to protect the deer and the habitat against competition from new species and from accidental introduction of parasites and diseases, against which there may be no natural immunity. Such accidents could cause the rapid extinction of the deer or other native species of animals and plants.

Fire

Vegetation in the lower Keys has been greatly influenced by fires, as have plant communities in all of south Florida for the past 2,000 to 3,000 years (Klukas 1973). Absence of fires from the normally open pinewoods results in replacement of pines by thick hardwood hammocks (Dickson 1955). This leads to the crowding-out of low ground cover and replacement by hardwood species which are inferior to pines as deer habitat, since in mature hardwood much of the food is beyond the reach of the deer. As food decreases, so does the number of deer using the area.

Both too few fires and too many fires may result in loss of pinewoods from the islands. During extended periods of over-protection from fire, ground litter accumulates to such high levels that when burning does occur, the fuel serves as a torch, creating intense heat that not only burns the crowns of the small pines but also ignites the root systems of large mature pines whose roots are exposed on the surface of the rocky substrate. The pines are thus killed. Alexander and Dickson (1972) noted that in a pine stand on Big Pine Key that had been fire-free for about 20 years, a wild fire killed most of the 4-12-foot pines except where heat was not excessive. The pinewoods on Little Pine Key are also the result of a severe fire which followed a prolonged fire-free period that allowed accumulation of high quantities of fuel. Frequent fires may also set back pine regeneration by killing small seedlings. Although Alexander and Dickson (1972) reported that *Pinus elliottii densa*, the variety of slash pine found in the Keys, was more fire tolerant than the *P. e. elliottii* variety on which much of the Florida research has been conducted, they indicated risk in burning stands of pines less than 12-15 feet tall and 2 inches d.b.h.

Because the evolution of the Key deer was subjected to the influence of a habitat affected by fire, controlled burning seems an important ingredient in a management program. Uncontrolled fires, under dry conditions and in areas of large fuel accumulation, kill both pines and hardwoods and destroy soil litter. Opened areas resulting from such fires have little or no cover and are

used little by deer. Uncontrolled fire also presents a hazard for fawns and other young animals.

To eliminate uncontrolled burning on the refuge, restrictions should be imposed on the use of fire. The area should be free of campfires and subject to local established burning restrictions. Fuel should be periodically reduced by low intensity controlled burning. Natural breaks in vegetation and firetrails should be developed and maintained to facilitate fire control.

Use of controlled fire in management results in the availability of new plant growth. Deer use in such areas increases shortly after the burn and continues at a high level for about 2 to 3 years. Burning serves to open the understory, enhancing regeneration of the pines; and, it serves to reduce ground litter to below hazardous levels.

Pinewoods should be subdivided into 30-40-acre sections by reclaiming old firetrails as well as making new trails. This would facilitate managing fires, aid in establishing differential burning schedules among the various blocks, establish areas of alternating cover and food, and make various areas more accessible to refuge personnel. As the type of fire desired is one of low intensity to prevent loss of desirable species, small strips should be burned individually.

Periodic controlled burning of pinewoods to maintain this habitat is recommended. In some areas where pine reestablishment is necessary, additional removal of palms in order to permit germination of pine seeds and growth of seedlings may be required.

The palms are fire resistant and recover rapidly from burning (see Habitat Clearing and Reseeding). To reopen buttonwood savannahs and release forbs, the frequency of burning should be at 4- to 5-year intervals to inhibit hardwood invasion. When maintained by burning such buttonwood prairies receive heavy deer utilization. It is important to monitor burned areas to note response of the vegetation to fire.

Burning should not take place from mid-March to August, in order to avoid loss of fawns and other animals reproducing during spring and summer months. Mid-March through mid-summer is the fawning season with peak parturition occurring in April and May; fawns have rarely been known to drop as late as September. Although rain occurs every month of the year, the pattern of rainfall tends to result in a wet season from May through September and a dry season from October through April. Thus, burning should follow light rains in February and early March.

Clearings

Clearing vegetation to manage deer habitat should be restricted to problem areas that require extensive renovation. Cleared areas create sites that supply deer browse as regrowth occurs; also, they enhance reestablishment of pines. Firetrails not only serve to manage fire, they also facilitate access to all parts of the key for both deer and refuge personnel.

Clearing may require use of chain saw or bulldozer. Chain saws have an advantage in that they are easy to use, are portable;

and, selective removal of plants is possible with only minor damage to surrounding vegetation. A bulldozer, while not as readily accessible to outer islands, is useful for quickly clearing fire-trails and large areas of thick vegetation. It is less selective than the chain saw and some damage to fringing mangrove and button-wood would occur in moving a dozer onto the islands from a barge. Bulldozing does break the oolitic limestone, thus creating sites for new plants to become established.

Reseeding

The only recommended use for reseeding is to aid in the reestablishment of pines on Little Pine Key. If it proves successful, and if it later seems desirable in long-range management, similar practices can be applied to other islands.

In order to have pine regeneration, the understory must be open, a condition which, in areas of Little Pine Key, will require clearing of the fast-growing palms and hardwood that compete with pine seedlings. After such clearing, native slash pine can be reseeded. Mature pine cones from trees on Big Pine, Little Pine, and No Name Keys should be collected in August to October to provide the necessary seeds. Following burning and clearing, to be completed by February or March, the seeds should be broadcast over the disturbed areas. By clearing and seeding before the rainy season, pines could germinate and become established before ground cover becomes thick enough to compete with the pine seedlings. It may prove necessary to repeat these efforts before

an adequate stand of seedlings results. Hopefully, natural reseeding will eventually supply seed for natural succession.

Water Development

Although evidence suggests that Key deer are capable of utilizing brackish water for at least a short time, they are generally restricted to those keys affording permanent fresh water and remain on other keys only during times when adequate rainfall provides fresh water. Thus, in planning for year-round maintenance of deer populations on outer islands, availability of acceptable water must be considered.

Maintaining existing available fresh water holes for the deer is the primary water management recommendation. This in itself should not drastically change present populations on those islands concerned.

Deer use for many islands is confined to the rainy months. By creating situations for year-round deer use, irreparable damage to vegetation may result because of low carrying capacities. It seems desirable to experimentally create a permanent fresh water supply on an island presently without a year-round source, to determine its effect on deer use. What effects, if any, this would have on the island's plant species, which currently are not subject to year-round browse pressure, could be determined. The success or failure of such manipulation would serve as a basis for future long-range management plans for outlying islands that currently do not host permanent deer populations.

Existing water holes can be improved by removing soil and organic accumulations that have nearly filled many of these solution basins. Reclamation of large basins may be achieved by skilled personnel using small surface charges of selected explosives or, in the case of smaller holes, the debris may be removed manually.

Use of clearing, burning, reseeding, and water development on refuge-owned lands is recommended as follows:

Big Pine Key - Small, natural grassy clearings in Watson Hammock should be burned to reduce hardwood species and reestablish annual grasses and forbs. By maintaining these small open plots, deer are supplied with feeding areas and open loafing sites. The schedule for maintaining these sites depends on the rate of regrowth of hardwoods, probably at intervals of 3 to 4 years.

The buttonwood savannah on the north end of Big Pine should be reopened by periodic burning at 2- to 3-year intervals. Firetrails should be reestablished in the pinewoods within the refuge; the pines should be burned on a rotation basis at intervals sufficient to allow seedlings to become established and to limit fuel accumulation. Locate, maintain, and monitor existing fresh water holes to note deer use.

Little Pine Key - To reestablish the pinewoods, the understory of palms and hardwoods should be removed by clearing and burning. Pines should be reseeded and should be control-burned periodically to be maintained. Rotation burning among blocks of pines separated by firetrails will maintain diversity. By burning and clearing in February and March, ground cover should be sufficiently removed to

enable new pine seedlings to become established after the August-October seedfall. Use of a bulldozer would be required to clear large sections of thick palms and hardwoods from the pines, taking care to leave the scattered live pines and clusters of palms and palmetto depressions for deer cover and fawn bedding sites. By breaking up the surface of the rocky substrate, pine seedlings may become more easily rooted. Experimental clearing should be started as soon as possible.

After initial clearing, subsequent trouble spots should be handled by use of a chain saw to control small segments of hardwoods and palms. In addition to leaving live pines, scattered palms, and palmetto, areas that should not be cleared are hardwood, hammock, buttonwood, and mangrove habitats.

Buttonwood savannahs should be opened by burning, first at 2-year intervals, then at 3-year intervals or when otherwise needed to prevent hardwood species from encroaching.

All fresh water holes should be located, maintained, and monitored to determine deer use.

Howe Key - It is recommended that Howe Key not be burned at this time. In the event that fresh water is established on this island, it is recommended that buttonwood and high areas where pines are located be opened by using fire and limited clearing to reestablish pines; however, this is a long-range proposal at best and should be done only if it appears that Howe Key will be needed to support surplus animals from Big Pine Key. The effects of experimentation on the Little Pine Key complex should be thoroughly analyzed and

considered to be a successful practice prior to any habitat manipulation on Howe Key.

Big Torch Key - The buttonwood savannah on the north end of this key should be burned at 2- to 3-year intervals. Locate, maintain, and monitor existing fresh water holes to note deer use.

Big Johnson, Little Johnson, Little Grassy, and Water Keys - Burning of buttonwood areas at frequent intervals should keep down hardwood species. In addition, low intensity burning of hardwood and hammock strips should maintain small openings for deer loafing and feeding sites.

Develop an experimental fresh water hole on Big Johnson and note the subsequent effects on deer and plant species. An attempt should be made to establish a permanent fresh water basin, possibly utilizing one of the depressions in the highest hardwood section of the Key. By clearing to rock and by proper sloping to prevent refilling with soil, this could serve as a catch basin and should maintain permanent fresh water (see Habitat Monitoring).

Clean out the existing fresh water hole on Water Key. Since there is a limited (diversity) food supply on this Key one would not expect a large deer population; but, present water would be maintained for the deer and other animals.

Other Keys - At this time no new water development is recommended for other islands that presently lack permanent fresh water. Only after evaluation of the Big Johnson Key experiment should other new sources be considered.

No other clearing should be permitted at this time. If habitat manipulation on Little Pine Key proves successful, judgment could then be made regarding similar management of the high regions on Howe Key. This should be done only as an extreme measure to handle surplus animals from Big Pine Key, should such become necessary.

Land Acquisition

Land acquisition to provide refuge has historically played a vital role in the recovery of Key deer from a low population level. Much private land that once had suitable deer habitat is now undergoing development and is so expensive that the cost involved in acquisition is probably prohibitive. However, the advantages to acquiring more land include providing more government-owned acreage on which a larger deer population may be maintained. While land adjacent to the refuge provides such acreage, isolated sections within housing developments on large keys additionally serve as daytime retreats, surrounded by open areas of cultivated shrubbery and other plants browsed by deer at night. These and holdings on other keys adjacent to Big Pine and Big Torch allow for greater dispersion of the deer, so that if they are exterminated from one area complete extinction is less likely.

The dispersal of government-owned lands over extensive areas, separated by private property or over a large number of islands separated by water, increases the problems of management and enforcement. The expense and time involved in patrolling such holdings

are greater than with a compact refuge and it is much less efficient. Maintaining marginal, isolated pockets of deer in rapidly developing areas increases the hazards to humans due to deer-related highway accidents, and increases damage to private property by deer feeding on shrubs and cultivated plants. Although there is now only minor pressure to remove one or two problem animals, as more residents settle in the Keys this problem will worsen (see Fencing). Finally, purchasing isolated properties is at best a stop-gap measure to maintain deer in areas where they will eventually disappear due to the increased pressures of people, dogs, and automobiles.

Because land acquisition is expensive, emphasis should not be placed on buying more isolated islands or tracts of land surrounded by private holdings. Lands that are available and that adjoin present holdings should be bought if at all possible. Isolated parcels that are presently owned could be traded for other sections bordering the refuge. Two sections on Middle Torch Key, for example, which are completely isolated and which will be difficult to maintain and patrol, could be traded for land adjacent to or within the refuge proper on Big Pine or Big Torch Keys.

Monitoring Populations

In managing any resource it is imperative to maintain a complete, constant awareness of the condition of the resource. It is especially vital when management involves rare or endangered species, like the Key deer, which might be quickly lost should

conditions become unfavorable. Therefore, constant monitoring of the habitat and the deer is necessary. Such surveillance also allows for detection of diseases and parasitism; and, in general, adds important information about aspects of the species' biology.

Surveillance of the Key deer population should emphasize trends in population size and the physical condition of the animals. Sex and age structure and reproductive performance also reflect the status of a population. To monitor aspects of the population and habitat, and to implement programs of management that optimize the island habitat for deer and other species, a full-time experienced biologist should be available. All mortalities should be autopsied. From healthy animals the following data should be recorded and/or collected: location and cause of death, weight, age, sex, antler characteristics, reproductive status, and parasites. From physically poor animals, in addition to the above, samples of tissue should be taken and signs of disease noted.

From the above data, any changes or trends should be compared to previous available data, as trends in physical characteristics of animals, and sex and age composition and reproductive performance are often early indicators of changes in the herd status. They also indicate range conditions or may herald impending problems. By noting parasites or disease signs in all mortalities, action may be taken to avoid epidemics which could eliminate the deer.

A standard census should be established and run periodically to note trends in populations on the refuge. It is suggested that

sections of the Big Pine Key and Big Torch Key refuges where roads exist, be established as census areas. Censuses should be scheduled once a month on set days and at a set hour, preferably between 2200 and 0100 hours. This is after traffic subsides, except on weekends, and is during a period of normal deer activity which usually decreases around 0100 hours. By keeping the time of month, time of day, and census routes constant, census data can be compared between years to detect trends in number of deer seen per mile.

Use of pellet counts and track counts are not feasible as census techniques for the islands. The porous, rocky substrate shows no tracks and pellets are frequently never seen as they quickly deteriorate or fall into holes. Thus, many areas show little evidence of deer use. Other areas, such as marl flats where tracks and pellets may remain for years, get only moderate use but appear to have heavy traffic. Fresh tracks and pellets should be used only to note trends in the use of water holes or other specific areas on the outer keys.

In addition to deer censuses, a record of total deer observed may serve to indicate trends in deer numbers and areas of activity. Although sex ratios of deer observed normally vary from one season to the next, knowledge of these ratios can be used to compare differences between years and to note changes from the normal ratio. Extensions of deer ranges indicating dispersal, possibly reflecting increased population levels, should be noted. Observations of does with fawns to note reproductive success should be interpreted with

caution since the Key deer fawn is relatively precocial, and often associates with most any deer that passes by. Thus, an observation of a doe with fawns does not necessarily indicate a true parental association.

Observations of animals or animal sign at selected sites on refuge lands, especially on the outer keys, should be made at 3-month intervals to determine deer trends. Noting deer tracks at water holes or on trails, numbers of fresh droppings, and signs of browse on key plant species (see Habitat Monitoring) should be used to determine utilization trends. These techniques are not designed to give numbers of deer on the islands but rather to indicate trends in population and centers of activity. They are more accurate if the same individual evaluates these areas each time in order to best compare any changes.

Those outer islands to be monitored are Water, Howe, Cutoe, Annette, Mayo, Little Grassy, Big Johnson, Little Johnson, and Little Pine Keys. It is important to monitor Little Pine and Big Johnson closely following any experimental manipulation of the pinewoods and water source; the responses of the deer and the vegetation will largely determine long-range plans for developing other islands. It is recommended that those keys which lie near islands of permanent deer populations, but which do not have permanent deer populations themselves, be monitored closely to determine the amount of deer use. As populations increase on islands with fresh water, surplus animals will move to these less suitable keys; but, they will have little or no use during times

of low deer populations. Therefore, evidence of changes in size of the deer herd will probably be seen first on these outer "indicator" islands before they are evident on the keys providing permanent residence. Such "indicator" islands are Big Johnson, Little Johnson, Little Grassy, Water, Howe, Annette, Mayo, and Cutoe.

Monitoring Habitat

Since the habitat reflects the extent of deer browse, and thus trends in the deer population, it is important to evaluate habitat changes. Early signs of trouble can be detected in time to protect the habitat by controlling deer numbers. Determination of the available deer food plants is a necessity before outer island management is undertaken. Key plant species in manipulated areas can be used to determine both plant response and deer use.

In monitoring habitat, it is important to note which plant species are utilized as food, the quantity and parts consumed, their rates of regrowth, reproduction and regeneration, and the sequence of plant succession. This is important both in areas where vegetation has been experimentally managed and in areas not managed but receiving deer use.

Key food species should be located for each major island complex and monitored at 3-month intervals to note the amount and location of browse pressure. Areas with extensive use would then require management. Key species on "indicator" islands (see Population Monitoring) will be important in noting trends in deer numbers.

Monitoring habitat using fenced exclosures (approximately 625 square feet in size) to exclude deer, yet maintain constant all other conditions, has proven effective. By noting the differences between the types and numbers of plants inside the exclosure to those outside, the effects of deer browse and trampling can be evaluated. In addition to the nine exclosures already established on Big Pine Key, the following exclosures are suggested for other islands: Big Torch Key - two in hardwood; Little Pine Key - two in pinewoods, two in hardwood, and one in buttonwood; Big Johnson Key - one in hardwood and one in high buttonwood; Little Johnson Key - one in hardwood; Little Grassy Key - one in hardwood and one in buttonwood; Water Key - one in the hardwood clump near the fresh water hole; Howe Key - one in hardwood; Annette Key - one in hardwood. In instances where more than one exclosure is suggested for a habitat type on the same island, they should be established apart in different segments.

The amount of fresh water available to the deer is an important aspect to be recorded. It is important to locate and monitor all permanent fresh water holes, especially during the dry season, during drought years, and following hurricanes. Monitoring should consist of salinity determinations, noting the amount of water available, and the condition of the basin.

Fencing

With increasing resident and tourist populations in the Key deer range, conflicts between deer and the human element have been compounded. Damage to private property by deer feeding on garden

and lawn plants has increased. Previously, local residents were willing to ignore such damage in exchange for the chance to see one of the rare deer. With higher deer populations the novelty has worn off and complaints have increased. Added to this problem is a recent type of local resident, one who has never known the rarity of the deer. Deer were numerous upon arrival and therefore they see no novelty with deer feeding in their gardens and yards.

Currently, roadkills may well serve to benefit the Key deer population as they contribute to population control; however, such accidents are undesirable due to property and potential human losses. Generally, as the deer population has increased so have roadkills. This relationship is not linear, for with new roads, housing developments, and increased use (local and tourist), kills have increased. Development has led to a patch-type habitat where deer requirements cannot be met in a given area; therefore, movements by deer have increased, adding to the problem. The recent plan for development in the Florida Keys (Milo-Smith and Associates, Inc., et al. 1970) provides for four lanes of highway across Big Pine Key. Supplementary roads parallel to it are proposed to handle local traffic. This will mean that deer crossing U.S. No. 1 will have to cross six lanes of traffic, increasing chances of being hit by an automobile. If a human fatality should ever be linked with the Key deer, public pressure could force drastic measures to keep deer off the roads. With highways located next to water and canals as in the Florida Keys, the chances for such a serious accident are greatly increased. In recent years there has been increasing

local support for fencing the Overseas Highway to protect the deer and decrease accidents. The practicality of any type of fencing must be considered to determine its desirability. From a practical standpoint, fencing this highway would be unrealistic due to highway access problems. Besides, the number of deer killed on this highway represents less than half the roadkills for Big Pine Key. From 1968 to 30 June 1973, of 210 roadkills found, 100 were on the Overseas Highway. In addition, lands next to the highway are private or state-owned and cannot be managed by the refuge system.

With increasing development in the Keys most of the deer will be confined to refuge lands. Even though available habitat in small blocks may lie outside refuge boundaries, increased roadkills will reduce the number of deer and damage in these areas. However, dispersal of excess animals into these areas from refuge lands and damage of private property next to refuge areas will increase as deer are confined to the refuge. This problem is compounded on Big Pine and Big Torch Keys where there are four and two major private developments, respectively, within the refuge. These subdivisions will receive heavy use by animals residing on adjacent refuge lands.

As human populations within residential developments increase, there will be more conflicts between deer and humans. Roadkills and property damage will increase. Problems will also arise with protection of the deer from illegal hunting as access through refuge lands must be maintained to accommodate these subdivisions. With heavily populated subdivisions within refuge areas, the misuse

of refuge lands will also occur. Penetration into refuge areas now rarely visited by humans will follow as residences increase. Protecting refuge lands from misuse and protecting the deer from human interference may become major problems of management on both Big Pine and Big Torch Keys.

To counteract these problems when they occur, refuge lands might be fenced. Prior to complete fencing of the refuge lands on Big Pine and Big Torch Keys (10 miles total fencing; Figs. 15 & 16), it would be desirable to establish an experimental area (Port Pine Heights Subdivision on Big Pine Key, total fencing 2-1/2 miles) to determine effectiveness and desirability of fencing. Effects on the deer and its habitat should be monitored. Port Pine Heights Subdivision is a desirable experimental area as it is the fastest growing subdivision completely surrounded by refuge lands and is already receiving heavy deer use. If fencing around Port Pine Heights Subdivision proves ineffective in protecting the deer, the fence would still be useful in that it would block access to the north end of Big Pine, a proposed inviolate area (see section on Visitor Management), and would limit access to Watson Hammock (Fig. 15).

If the Port Pine Heights experimental area proves successful, then other areas should be fenced as the need arises. All fencing would be on refuge and/or Audubon-owned land; and, all refuge and Audubon land would be continuous, allowing deer movement within these areas. A 6-foot-high fence seems sufficient since deer have been successfully held in captivity within a 5-foot-high fence at refuge headquarters. Fences ending at the water's edge should be

extended into the water to low tide level. This would be accomplished with the use of land fill and would discourage deer from moving around the edge of the fence. At points where the fence meets access roads, cattle guards (4 on Big Pine, 2 on Big Torch; Figs. 15 & 16) would be constructed. Cattle guards, which would be made of galvanized pipe, would be 30 feet in length and wider than the road so as not to be a traffic hazard. Depth beneath the bridge would be a minimum of 2 feet. All fencing along roads would be placed back from refuge boundaries so as to be hidden from view by vegetation where possible. Fence lines would be kept cleared of vegetation so they could serve as fire lanes to keep fire from private lands.

The high initial cost and maintenance could be spread over a number of years as only those subdivisions where problems occurred would be fenced at any one time. As the problems increased this would gradually lead to complete enclosure of refuge lands on Big Pine Key and Big Torch Keys. The artificiality of fencing in the deer population may not be as it appears, for it is simply creating an island within an island. Naturally, the number of animals that could be accommodated after fencing would be less since less food and living space would be available.

Some problems may arise from deer moving (swimming) around edges of the fence from refuge into private lands. Animals causing extensive damage could be trapped and removed to other areas (see section on Animal Removal). Problem deer remaining in subdivisions would require capturing and moving to refuge lands. These problems would not seem too serious since deer should be low in numbers near population centers and along highways.

Although limited dispersal within the fenced refuge may lead to crowding and therefore habitat destruction, some dispersal to Howe and Annette Keys from Big Pine and to Water Key from Big Torch would help to alleviate this problem. Because of the "island within an island" effect this may be no more of a problem than now. Lower mortality due to decreased roadkills may make trapping and removal necessary; however, if possible, the major loss of deer should result from roadkills, mosquito ditches, environmental- (storms) and stress-produced mortalities, and dispersal.

The fencing should result in a better working relationship between the government and the local residents. Roadkills would still occur inside refuge areas due to subdivision access, but speed limits could be more easily controlled than on the Overseas Highway, which is the only road in and out of the Keys. The fence system might eventually eliminate the need for reduced speed limit regulations on the Overseas Highway. The protection of deer and control of refuge lands would be more convenient as deer and refuge land would be confined within a fence. Cost of law enforcement could thereby be reduced.

Animal Removal

It is very difficult to consider animal removal when dealing with an endangered species. However, increased private development may disrupt existing natural population control mechanisms and lead to overpopulation. If damage is allowed to occur the carrying capacity of the habitat will invariably decrease and may be

extensively damaged. To avoid this, the habitat and deer population should be kept in balance, possibly through deer removal prior to habitat damage. Deer resident outside of refuge lands pose a special problem. To maintain good public relations, deer damage to private areas must be minimized. Any deer removal should be gradual, only from problem areas, include only problem deer, and selectively done. Data now indicate that buck control is probably accomplished through "natural" mortality (roadkills and social aggression) and dispersal. Hence, control of the adult buck portion of the population seems unnecessary. Because reproduction by adult females controls population numbers, the removal of selected does may provide sufficient control. Live trapping and drugs should be used and all collections handled by refuge personnel.

Priorities should be given to restocking deer on refuge-owned lands where the native population had been eliminated. Low numbers on outer islands usually mean deer are within the carrying capacity of their range. Transplanting deer into these areas may only disrupt the stability of the native herd. Only in rare instances where deer have been eliminated from an island due to either natural (hurricanes) or unnatural (poaching) causes can such transplanting be justified. One advantage of having deer on the three proposed complexes (Big Pine, Bog Torch, and Little Pine) would be the comparative isolation of these herds. Through this isolation the possibility of a serious disease affecting all herds at once is lessened. Affected complexes could be restocked from uninfected ones.

Removal of excess deer over those needed for restocking should be for scientific studies. Selecting adult does from problem areas is the most effective way to control deer numbers; and, it provides a means to monitor herd condition (see section on Population Monitoring). A planned program of selective removal would require the collection of only a few animals at any one time. Hopefully, this would reduce the level of any adverse public reaction.

Excess animals can be used to supply museums and zoological gardens. However, once such populations are established this outlet will be eliminated. These gardens will have their own population problems and will probably supply other gardens with animals. But, Key deer from zoological gardens <u>must never be considered as a reserve for restocking Key deer ranges</u>. It is very likely that the integrity of this race will be lost as representatives are reared and transferred around the world.

It is believed that public hunting as a population control measure is to be avoided at all costs. At best only a very limited recreation outlet can be provided because of the small number of participants that can be accommodated. However, more critical are the problems of the proximity of private properties and the adverse publicity related to the hunting of an endangered species. In the face of these factors, herd reduction <u>must</u> be accomplished through other techniques should overpopulation be determined. It must be cautioned that such a decision must be placed in its proper context; namely, a small population in a shrinking habitat.

Create New Habitat

Management should emphasize the development of native habitat so as to reflect the earlier history of this deer. Emphasis must be placed on reestablishing and/or maintaining those conditions under which the deer evolved. Presumably, they have survived in this environment at lower than present population levels for a long time without management. The choice is to maintain the Key deer, or maintain a large number of deer in the Florida Keys. The creation of new habitat should only be considered when insufficient habitat is threatening deer extinction. Even then, new habitat construction must proceed gradually so results can be evaluated.

The creation of new habitat is not limited to any one key. Dredge and fill operations could be utilized to elevate any low areas above high tide level; thus, all keys could be "improved" by filling low marl flats. Dredging should be done within the mangrove fringe around the edge of each island so mangroves are not destroyed. Canals created by the dredge operations should not connect to open water. Such connections would allow sedimentation produced by the dredging to damage marine habitats and also offer easy access by boat which would be undesirable. The amount of fill obtained would depend on the length, width, depth, and number of canals dredged. Excess fill could be sold to help cover cost of the operations as moving equipment to the outer keys would be costly.

The type of habitat developed could be controlled by the depth of fill applied to these areas. If pines were desirable, a greater depth of fill would be needed and pine and palms would have to be

established after the salt had leached. If grasses and hardwoods were preferred, less fill would be required and these plants could establish themselves through natural succession.

By creating more habitat on keys that already have deer populations, deer numbers can be expected to increase. This may create more management problems, as overpopulation may result. Limited food within a restricted area may retard reproductive rates and thereby act as a population control mechanism. With additional food in the same limited area this control mechanism may be disrupted. On keys not presently suitable for deer habitation, the creation of suitable habitat may also disrupt population control mechanisms. Evidence indicates that deer dispersing from keys with suitable habitat swim to keys with marginal habitat and remain only during favorable periods (i.e. rainy season). These marginal keys, as they now exist, offer additional food during these periods. But, because of the lack of year-round fresh water the deer must return to suitable islands or succumb to the environment. Additional losses invariably occur while moving between keys. The rainy season also corresponds to the fawning season and does moving to marginal keys during this period may have fawns on these keys. Later, when fresh water is gone, the doe must return; if the fawns are unable to do so they perish. By "improving" these unsuitable keys, such losses that have previously contributed to population control may be eliminated.

Visitor Management

The Key Deer National Wildlife Refuge offers unique fauna and flora within refuge lands, and fishing within refuge waters. In planning for visitor use the primary goal to maintain the Key deer must not be forgotten. With more tourism, the demand for visitor use will increase. To avoid conflicts between the primary goal of maintaining the deer and those secondary goals for human visitation, a land use policy must be established. All outer keys, Big Torch Key, and the north end of Big Pine Key should be maintained as inviolate areas. With the exception of carrying out research and management practices, these areas should be free from human interference.

Human visitation to inviolate areas could disrupt management programs and result in damage to the habitat. Evidence of campers, bottle collectors, and even the U.S. Marines can already be observed in some areas. The Marines, while conducting training missions on privately-owned No Name Key, accidentally started a fire with a flare. Such uncontrolled fires must be avoided.

Watson Hammock on Big Pine Key needs special consideration because of its unique diversity of plant and animal life. It is also the most desirable Key deer habitat in the entire refuge. This area, with its large trees and high ground, offers cover and protection during storms. It is difficult to completely forbid access to such an area because of the many attractions; but, because of the area's small size, uncontrolled visitation would easily destroy its uniqueness. Access should be limited to supervised visitation.

For the remainder of federally-owned lands within the refuge, access should be limited to daytime use. Activities such as wildlife observation and sightseeing are acceptable for these land areas; but vehicles, with the exception of refuge and emergency equipment, should be prohibited. Collection of plants or animals should be denied except for scientific purposes as authorized by proper permits.

Audubon Society-owned lands, controlled by the refuge, need special consideration. Currently, permission has been granted by the Audubon Society to various organized groups including Boy Scouts, Girl Scouts, and numerous church organizations for overnight camping. These activities must be confined to Audubon lands and provisions made for organized and managed areas for camping and fires. A practice of planned patrol is essential. If these matters cannot be properly administered, it will be necessary to restrict such public use.

Establishment of a visitors' center, as once planned and manned by a recreation specialist, seems desirable. Visitors could be routed to this area, freeing the current headquarters for its established function, the maintenance of the Key Deer Refuge. Heavy visitor use of refuge lands should be confined to an area adjoining the visitors' center. Multiple use through reestablishment of the deer "hospital" surrounded by a nature trail built to display the area's uniqueness would help confine visitors.

Having the visitors' center approximately centered within the Big Pine Key refuge lands will increase traffic into this area.

Access roads into and out of the center must be maintained free of traffic hazards. Speed limits through the refuge should be lowered to 25 mph, especially if the area is ever fenced (see section on Fencing). Lowered speed limits would reduce chances of accidents. With reduced auto speeds, deer may more fully utilize roadside areas, thereby providing a "wildlife auto trail" through the refuge.

LITERATURE CITED

Alexander, T. R., and J. D. Dickson, III. 1972. Vegetational changes in the National Key Deer Refuge - II. Q. J. Florida Acad. Sci. 35(2):85-96.

Bandy, P. J., W. D. Kitts, A. J. Wood, and I. M. Cowan. 1957. The effect of age and the plane of nutrition on the blood chemistry of the Columbian black-tailed deer (Odocoileus hemionus columbianus). Can J. Zool. 35:283-298.

Barbour, T., and G. M. Allen. 1922. The white-tailed deer of eastern United States. J. Mammal. 3(2):65-78.

Benbrook, E. A., and W. Sloss. 1961. Veterinary clinical parasitology. 3rd ed. Iowa State University Press, Ames. 340pp.

Dickson, J. D., III. 1955. An ecological study of the Key deer. Florida Game and Fresh Water Fish Comm. Tech. Bull. 3. 104pp.

Gunvalson, V. E., A. B. Erickson, and D. W. Burcalow. 1952. Hunting season statistics as an index to range conditions and deer population fluctuations in Minnesota. J. Wildl. Manage. 16(2):121-131.

Harlow, R. F., and F. K. Jones, Jr. 1965. The white-tailed deer in Florida. Florida Game and Fresh Water Fish Comm. Tech. Bull. 9. 240pp.

Hawkins, R. E., and W. D. Klimstra. 1970. A preliminary study of the social organization of white-tailed deer. J. Wildl. Manage. 34(2):407-419.

Karstad, L. 1962. Viral and rickettsial diseases of deer: A review. Proc. Natl. White-tailed Deer Dis. Symp. 1:138-144.

Key Deer Investigation Progress Reports. 1968-1972. Cooperative Wildlife Research Laboratory, Southern Illinois University at Carbondale.

Klukas, R. W. 1973. Control burn activities in Everglades National Park. Proc. Tall Timbers Fire Ecol. Conf. 12:397-425.

Ludwig, J. R. 1967. A comparison of age determination techniques for white-tailed deer of southern Illinois. M.A. Thesis, Southern Illinois Univ. 30pp.

Milo Smith and Associates, Inc., and Hale and Kullgren, Inc. 1970. Environment and identity: A plan for development in the Florida Keys. HUD Proj. P-116. Ser. 1-1. 201pp.

Morgan, B. B., and D. A. Hawkins. 1949. Veterinary helminthology. Burgess Publ. Co., Minneapolis. 400pp.

Peirce, A. W. 1957. Studies on salt tolerance of sheep. I. The tolerance of sheep for sodium chloride in the drinking water. Aust. J. Agric. Res. 8:711-722.

Peirce, A. W. 1959. Studies on salt tolerance of sheep. II. The tolerance of sheep for mixtures of sodium chloride and magnesium chloride in the drinking water. Aust. J. Agric. Res. 10:725-735.

Phillips, J. C. 1920. Skull measurements in the northern Virginia deer. J. Mammal. 1(3):130-133.

Severinghaus, C. 1949. Tooth development and wear as criteria of age in white-tailed deer. J. Wildl. Manage. 13(2):195-216.

Teeri, A. E., W. Virchow, N. F. Colovos, and F. Greeley. 1958. Blood composition of white-tailed deer. J. Mammal. 39:269-274.

U.S. Fish and Wildlife Service Narrative Reports. 1939-1967. Key Deer Information. Bureau of Sport Fisheries and Wildlife, Atlanta, Georgia.

VanTets, P., and I. M. Cowan. 1966. Some sources of variation in the blood sera of deer (Odocoileus) as revealed by starch gel electrophoresis. Can J. Zool. 44:631-647.

Weeth, H. J., and L. H. Haverland. 1961. Tolerance of growing cattle for drinking water containing sodium chloride. J. Anim. Sci. 20:518-521.

Wood, J. E., T. S. Bickle, W. Evans, J. C. Germany, and V. W. Howard, Jr. 1970. The Fort Stanton mule deer herd (some ecological and life history characteristics with special emphasis on the use of water). New Mexico State Univ. Agric. Exp. Sta. Bull. 567. 32pp.

Youatt, W. G., L. J. Verme, and D. E. Ullrey. 1965. Composition of milk and blood in nursing white-tailed does and blood composition of their fawns. J. Wildl. Manage. 29:79-84.

TABLES

Table 1. Population estimates using data from 10-mile census on Big Pine Key, Key Deer National Wildlife Refuge, October, 1968 through June, 1973.

Quarter	Population Estimates						
				Yearlings			
	All Deer	Adult Does	Adult Bucks	Bucks	Does	Both	Fawns
Oct-Dec 68	242 ± 140	---[a]	---	---	---	---	20 ± 12
Jan-Mar 69	61 ± 9	19 ± 5	12 ± 7	---	---	---	21 ± 5
Apr-June 69	70 ± 13	29 ± 6	7 ± 2	14 ± 20	8 ± 1	25 ± 6	---[b]
Jul-Sep 69	42 ± 7	24 ± 7	9 ± 4	7 ± 2	4 ± 0	10 ± 2	---
Oct-Dec 69	67 ± 12	15 ± 3	---	8 ± 4	---	21 ± 12	19 ± 5
Jan-Mar 70	67 ± 5	33 ± 5	5 ± 2	9 ± 3	4 ± 0	12 ± 3	17 ± 2
Apr-June 70	98 ± 10	56 ± 5	10 ± 1	9 ± 3	10 ± 0	21 ± 4	---
Jul-Sep 70	83 ± 8	44 ± 4	12 ± 2	17 ± 10	10 ± 2	23 ± 6	---
Oct-Dec 70	127 ± 12	59 ± 8	17 ± 5	10 ± 3	12 ± 5	20 ± 5	21 ± 4
Jan-Mar 71	156 ± 11	55 ± 5	23 ± 9	26 ± 9	13 ± 5	42 ± 12	49 ± 11
Apr-June 71	117 ± 5	61 ± 2	23 ± 3	15 ± 5	14 ± 2	31 ± 6	---
Jul-Sep 71	96 ± 5	57 ± 3	20 ± 3	13 ± 3	10 ± 0	21 ± 2	---
Oct-Dec 71	111 ± 5	48 ± 2	20 ± 6	9 ± 2	13 ± 2	23 ± 3	25 ± 3

Table 1. Continued.

Quarter	Population Estimates						
				Yearlings			
	All Deer	Adult Does	Adult Bucks	Bucks	Does	Both	Fawns
Jan-Mar 72	108 ± 12	49 ± 7	---	10 ± 5	7 ± 0	17 ± 3	14 ± 1
Apr-June 72	96 ± 9	47 ± 4	18 ± 3	---	15 ± 4	39 ± 15	---

[a]Insufficient data for population estimate.

[b]Insufficient data and fawns not counted for population estimates during these periods.

Table 2. Results of weekly censuses along 10-mile route, Key Deer National Wildlife Refuge, July, 1968-June, 1972

Month & Year	Number Of Censuses	Total No. Deer Observed	Number Deer/Mile	Month & Year	Number Of Censuses	Total No. Deer Observed	Number Deer/Mile
July 68	4	18	0.45	July 69	5	22	0.44
Aug 68	5	24	0.48	Aug 69	4	16	0.40
Sept 68	4	23	0.57	Sept 69	4	14	0.35
Oct 68	5	18	0.36	Oct 69	5	10	0.20
Nov 68	4	26	0.65	Nov 69	4	16	0.40
Dec 68	4	29	0.73	Dec 69	4	35	0.88
Jan 69	5	42	0.84	Jan 70	5	43	0.86
Feb 69	4	26	0.65	Feb 70	4	35	0.88
Mar 69	4	27	0.68	Mar 70	4	24	0.60
Apr 69	4	37	0.93	Apr 70	5	54	1.08
May 69	5	55	1.10	May 70	4	36	0.90
June 69	4	26	0.65	June 70	4	23	0.58

Table 2. Continued.

Month & Year	Number Of Censuses	Total No. Deer Observed	Number Deer/Mile	Month & Year	Number Of Censuses	Total No. Deer Observed	Number Deer/Mile
July 70	5	25	0.50	July 71	5	62	1.24
Aug 70	4	21	0.52	Aug 71	4	23	0.58
Sept 70	4	16	0.40	Sept 71	5	45	0.90
Oct 70	5	16	0.32	Oct 71	4	51	1.28
Nov 70	4	35	0.70	Nov 71	4	61	1.55
Dec 70	5	48	0.96	Dec 71	4	85	2.13
Jan 71	4	66	1.65	Jan 72	4	27	0.68
Feb 71	4	68	1.70	Feb 72	2	20	1.00
Mar 71	4	55	1.38	Mar 72	5	55	1.20
Apr 71	4	78	1.91	Apr 72	4	43	1.08
May 71	4	63	1.51	May 72	4	40	1.00
June 71	4	23	0.51	June 72	3	9	0.30

Table 3. Road census data from October, 1968 through June, 1972.

Year	% Bucks	% Does	% Fawns	Deer/Mile
1969	15	46	39	0.65
1970	9	48	43	0.65
1971	12	55	33	1.11
1972	19	54	27	1.14

[a]Data used for calculations were from October of preceding year through March of year listed, as few fawns were active during April-September at night.

Table 4. Sex and age ratios of deer captured during January, 1968 through June, 1973.

Year[a]	Adult Buck	Adult Doe	Yearling Buck	Yearling Doe	Fawn Buck	Fawn Doe	Ratio Buck:Doe:Fawn	Ratio Yg. Yg. Buck:Doe	Ratio Fawn Fawn Buck:Doe	Ratio Doe:Yearling
-1968	0	1	0	0	1	0	0.00:1:1.00	- :-	- :-	1: -
1968-69	10	9	1	4	13	3	1.11:1:1.78	0.25:1	4.33:1	1:0.56
1969-70	3	14	4	3	11	4	0.21:1:1.07	1.67:1	2.75:1	1:0.50
1970-71	12	20	5	7	18	6	0.60:1:1.20	0.71:1	3.00:1	1:0.60
1971-72	5	12	3	5	15	8	0.42:1:1.92	0.60:1	1.88:1	1:0.67
1972-73	1	1	4	1	10	5	1.00:1:15.0	4.00:1	2.00:1	1:5.00
1973-74	1	3	1	2	2	3	0.33:1:1.67	0.50:1	0.67:1	1:1.67
Totals	32	61	18	22	70	29	0.52:1:1.62	0.82:1	2.41:1	1:0.66

[a]Data are grouped into yearly periods beginning on 1 April to enable evaluation of the impact of the fawn and yearling age classes each year.

Table 5. Locations of highway mortalities of Key deer listed by calendar year, January, 1968 through June, 1973.

Location	Year						Total
	1968	1969	1970	1971	1972	1973[a]	
Big Pine Key							
Overseas Highway	15 (57.7%)[b]	21 (50.0%)	10 (33.3%)	18 (35.3%)	14 (48.3%)	16 (69.6%)	94 (46.8%)
State Route 940	5 (19.2%)	8 (19.0%)	12 (40.0%)	19 (37.2%)	7 (24.1%)	6 (26.1%)	57 (28.4%)
Other	6 (23.1%)	13 (31.0%)	8 (26.7%)	14 (33.3%)	8 (27.6%)	1 (4.3%)	50 (24.9%)
Total	26	42	30	51	29	23	201
% killed on Big Pine	92.8%	91.3%	96.8%	82.2%	80.6%	82.1%	87.0%
Other Keys							
No Name Key	0	0	0	4	2	4	10
Little Torch Key	1	1	0	3	3	0	8
Middle Torch Key	0	0	1	0	0	0	1
Big Torch Key	0	1	0	0	0	0	1
Ramrod Key	1	1	0	4	2	0	8
Cudjoe Key	0	1	0	0	0	1	2
Total	2	4	1	11	7	5	30
% killed on other Keys	7.2%	8.7%	3.2%	17.8%	19.4%	17.9%	13.0%

Table 5. Continued.

Location	Year						Total
	1968	1969	1970	1971	1972	1973[a]	
Total killed on all Keys	28	46	31	62	36	28	231

[a]Data includes deer killed up through June of 1973.

[b]Numbers in parentheses represent the percent of the deer lost on Big Pine Key for the year at the designated location.

Table 6. Sex and age ratios of deer observed during March, 1968 through 15 June 1972.

Date[a]	Adult Buck	Adult Doe	Yearling Buck	Yearling Doe	Fawn	Ratio Buck:Doe:Fawn	Ratio Yearling Buck:Yearling Doe	Ratio Doe:Yearling
March 1968	9	30	5	6	1	0.30:1:0.03	0.83:1	1:0.37
Apr 68-Mar 69	292	563	48	152	421	0.52:1:0.75	0.32:1	1:0.36
Apr 69-Mar 70	331	1,067	249	404	858	0.31:1:0.80	0.62:1	1:0.61
Apr 70-Mar 71	1,029	3,462	824	1,032	1,808	0.30:1:0.52	0.80:1	1:0.54
Apr 71-Dec 71[b]	668	2,356	606	606	753	0.28:1:0.31	1.00:1	1:0.51
Apr 72-June 72[c]	65	341	106	77	43	0.19:1:0.13	1.38:1	1:0.54
Totals	2,394	7,819	1,838	2,277	3,884	0.31:1:0.50	0.81:1	1:0.53

[a]Data are grouped into years beginning on 1 April to enable evaluation of the impact of the fawn and yearling age classes each year.

[b]There were no observations during January-March, 1972.

[c]Observations were discontinued on 15 June 1972.

Table 7. Observations of Key deer recorded each month, March, 1968 through 15 June 1972.[a]

Month	Adult Buck	Adult Doe	Yearling Buck	Yearling Doe	Fawn	Ratio Buck:Doe:Fawn	Ratio Yearling Buck:Yearling Doe	Ratio Doe:Yearling
April	175	843	225	227	7	0.21:1:0.01	0.99:1	1:0.54
May	212	864	262	209	89	0.24:1:0.10	1.25:1	1:0.54
June	292	938	254	313	220	0.31:1:0.23	0.81:1	1:0.60
July	281	788	239	282	257	0.36:1:0.33	0.85:1	1:0.66
August	226	622	200	216	285	0.36:1:0.45	0.93:1	1:0.67
September	158	429	117	124	228	0.37:1:0.53	0.94:1	1:0.56
October	281	648	123	156	406	0.43:1:0.63	0.79:1	1:0.43
November	172	529	108	129	421	0.33:1:0.80	0.84:1	1:0.45
December	235	721	120	226	575	0.32:1:0.80	0.53:1	1:0.48
January	136	452	81	139	428	0.30:1:0.95	0.58:1	1:0.49
February	106	395	58	121	460	0.27:1:1.16	0.48:1	1:0.45
March	120	590	51	135	508	0.20:1:0.86	0.38:1	1:0.32
Totals	2,394	7,819	1,838	2,277	3,884	0.31:1:0.50	0.81:1	1:0.53

[a]Observations were not made during January-March, 1972 or after 15 June 1972.

Table 8. Sex and age ratios of highway mortalities of Key deer, January, 1968 through June, 1973.

Year[a]	Adult Buck	Adult Doe	Yearling Buck	Yearling Doe	Fawn Buck	Fawn Doe	Ratio Buck:Doe:Fawn	Ratio Yg. Yg. Buck:Doe	Ratio Fawn Fawn Buck:Doe	Ratio Doe:yearling
-1968	1	2	1	0	2	0	0.50:1:1.00	- :1	- :1	1:0.50
1968-69	8	6	6	1	5	2	1.33:1:1.17	6.00:1	2.50:1	1:1.17
1969-70	15	5	13	3	8	6	3.00:1:2.80	4.33:1	1.33:1	1:3.20
1970-71	7	9	6	3	7	4	0.78:1:1.22	2.00:1	1.75:1	1:1.00
1971-72	14	14	12	4	6	5	1.00:1:0.78	3.00:1	1.20:1	1:1.14
1972-73	16	5	7	4	2	3	3.20:1:1.00	1.75:1	0.67:1	1:2.20
1973[b]	8	7	2	0	0	1	1.14:1:0.14	- :1	- :1	1:0.28
Totals	69	48	47	15	30	21	1.44:1:1.06	3.13:1	1.43:1	1:1.29

[a]Data are grouped into yearly periods beginning on 1 April to enable evaluation of the impact of the fawn and yearling age classes each year.

[b]Includes only data collected during April through 15 June.

Table 9 . Reproductive data gathered from female Key deer during November through June of each year beginning January, 1968 through June, 1973.

Age of Doe	Total Number of Does Examined	Number Pregnant	Number Lactating	Single Fetuses M	Single Fetuses F	Single Fetuses UK	Twin Fetuses[a] M	Twin Fetuses[a] F	Twin Fetuses[a] UK	Total Fetuses	Fetal Sex Ratio M:F	Fetuses Per Doe	Fawns Produced Per Doe
½-1 yr.	6	0	0	0	0	0	0	0	0	0	---	0.00	0.00
1-2 yrs.	8	0	0	0	0	0	0	0	0	0	---	0.00	0.00
2-3 yrs.	11	7	1	4	0	2	0	2	0	8	4:2	0.73	0.82
3-4 yrs.	8	7	1	2	2	2	0	2	0	8	2:4	1.00	1.12
4-5 yrs.	4	3	1	2	0	0	2	0	0	4	4:0	1.00	1.25
5-6 yrs.	4	3	1	1	2	0	0	0	0	3	1:2	0.75	1.00
6-7 yrs.	0	0	0	0	0	0	0	0	0	0	---	----	----
7-8 yrs.	1	0	1	0	0	0	0	0	0	0	---	0.00	1.00
Adults (age unknown)	7	6	0	2	0	0	3	3	2	10	5:3	1.43	1.43
Totals	49	26	5	11	4	4	5	7	2	33	16:11	0.67	0.78

[a]M = male; F = female; UK = sex unknown.

Table 10. Survival of Key deer from one age class to the next based on 110 marked animals of known fate.

Age Class	Sex	N	% Dying in This Age Class	% Survival to Next Age Class
0-6 mo.	Male	17	35.3%	64.7%
	Female	8	37.5%	62.5%
	Total	25	36.0%	64.0%
6-12 mo.	Male	32	9.4%	90.6%
	Female	14	7.2%	92.8%
	Total	46	8.7%	91.3%
1 year	Male	31	32.3%	67.7%
	Female	22	13.6%	86.4%
	Total	53	24.5%	75.5%
2 years	Male	23	34.8%	65.2%
	Female	24	8.3%	91.7%
	Total	47	21.3%	78.7%
3 years	Male	12	25.0%	75.0%
	Female	28	10.7%	89.3%
	Total	40	15.0%	85.0%
4 years	Male	7	42.9%	57.1%
	Female	20	5.0%	95.0%
	Total	27	14.8%	85.2%
5 years	Male	4	25.0%	75.0%
	Female	17	5.9%	94.1%
	Total	21	9.5%	90.5%
6 years	Male	2	0.0%	100.0%
	Female	13	30.8%	69.2%
	Total	15	26.7%	73.3%
7 years	Male	3	100.0%	0.0%
	Female	7	28.6%	71.4%
	Total	10	50.0%	50.0%
8 years	Male	0	-----	-----
	Female	3	66.7%	33.3%
	Total	3	66.7%	33.3%
9 years	Male	0	-----	-----
	Female	0	-----	-----
	Total	0	-----	-----

Table 11. Recorded Key deer mortality, January, 1968 through June, 1973.

Sex and Age	Highway Mortality	Drowning Mortality	Capture & Marking Mortality	Combat Mortality	Miscellaneous	Unknown	Total
Adult Male	69	1	7	7	1	6	91 (29.9%)
Adult Female	48	1	2	0	0	8	59 (19.4%)
Yearling Male	47	0	3	0	2	1	53 (17.4%)
Yearling Female	15	0	3	0	1	2	21 (6.9%)
Fawn Male	30	6	3	0	3	3	45 (14.8%)
Fawn Female	21	4	0	0	1	2	28 (9.2%)
Fawn (Unknown)	0	2	0	0	0	1	3 (1.3%)
Unknown	1	0	0	0	0	3	4 (0.3%)
Total	231	14	18	7	8	26	304 (100 %)

[a]Numbers in parentheses represent percent of the total number killed.

Table 12. Summary of mean monthly movements (in feet) for Key deer, 1969-1972, Key Deer National Wildlife Refuge. Number in parentheses represents the number of random consecutive daily locations used to figure movement index.

Month	AM	AF	YM	YF	FM	FF
January	1766-7[a](158)[b]	1121-8(225)	2084-2(61)	1034-2(62)	1326-4(121)	1207-4(118)
February	1776-7(177)	1112-7(174)	2258-2(54)	1259-2(56)	1449-4(110)	1154-4(112)
March	1799-7(201)	1018-7(196)	2258-2(62)	1172-3(82)	1588-4(111)	1058-4(121)
April	2414-11(291)	1158-11(300)	1577-8(196)	1311-4(114)	350-4(36)	559-3(40)
May	1894-11(300)	1201-14(339)	1687-9(188)	1693-4(113)	473-10(136)	661-4(38)
June	1675-11(280)	1177-14(326)	1457-7(141)	930-4(101)	613-4(67)	777-1(25)
July	1434-11(226)	1229-14(296)	1434-8(156)	1328-4(98)	892-6(33)	757-1(28)
August	1796-12(225)	1281-15(334)	1388-6(194)	1176-5(121)	799-6(53)	786-1(14)
September	1866-9(154)	1403-13(345)	2672-4(72)	1347-6(168)	1287-9(133)	837-2(26)
October	2640-9(176)	1465-13(354)	3120-3(44)	1294-6(154)	1674-5(119)	1829-1(31)
November	2537-8(146)	1504-13(217)	3174-2(39)	1302-6(135)	1624-6(100)	1186-3(41)
December	2203-12(235)	1329-14(305)	2353-4(67)	1565-4(122)	1365-7(148)	1318-5(93)

[a]Number of deer radio-tracked to find average monthly movement index.

[b]Number of random, consecutive daily locations used to establish movement index.

Table 13. Summary of the mean monthly range (in acres) of Key deer, Key Deer National Wildlife Refuge, 1969-1972.

Month	AM	AF	YM	YF	FM	FF
January	213.9(7)[a]	103.5(8)	252.7(2)	96.2(2)	130.6(6)	125.9(4)
February	230.8(7)	110.8(7)	244.2(2)	135.3(2)	127.5(6)	108.1(4)
March	292.4(7)	869(7)	250.5(2)	94.2(3)	138.8(7)	102.2(4)
April	320.9(10)	113.7(11)	290.3(8)	268.8(4)	41.6(1)	29.6(1)
May	395.2(10)	125.8(14)	283.6(7)	169.6(4)	23.1(5)	31.9(2)
June	274.7(10)	114.0(14)	226.0(6)	192.7(4)	40.7(3)	51.6(1)
July	212.0(10)	103.7(14)	133.0(7)	189.7(4)	45.3(3)	43.0(1)
August	225.7(11)	117.6(14)	168.7(6)	143.6(5)	39.0(3)	49.0(1)
September	488.1(8)	159.5(13)	397.9(4)	138.4(6)	105.7(5)	66.0(1)
October	287.5(7)	190.9(13)	639.5(2)	142.6(6)	256.4(5)	478.4(1)
November	410.3(7)	152.6(12)	375.3(2)	122.7(6)	221.8(4)	104.4(2)
December	324.1(10)	124.9(13)	353.1(3)	190.6(5)	137.3(6)	86.2(5)

[a] Number of deer radio-tracked to establish size of range.

Table 14. Five vegetation types used by Key deer according to time of day and year, Big Pine Key, Florida.

Age & Sex Classes	January-March					April-June					July-September					October-December					Time
	D[a]	P	B	H	M	D	P	B	H	M	D	P	B	H	M	D	P	B	H	M	
Adult buck	8[b]	7	42	30	13	24	19	33	10	14	26	24	18	20	12	16	36	18	27	3	Night
	0	8	45	36	11	2	19	40	23	16	2	22	30	33	13	4	40	12	35	9	Day
Adult doe	20	28	24	22	6	25	40	20	12	3	22	46	16	12	4	26	38	17	13	6	Night
	2	21	26	38	13	8	37	26	21	8	6	44	21	23	6	6	37	24	23	10	Day
Yearling buck	34	40	10	9	7	18	33	28	8	13	26	20	22	10	22	24	19	26	24	7	Night
	1	18	30	30	21	6	42	27	14	11	6	27	28	23	16	3	25	20	36	16	Day
Yearling doe	42	6	42	7	3	15	41	26	15	3	17	39	19	19	6	28	31	17	19	5	Night
	2	0	72	6	20	7	47	22	21	3	2	35	21	35	7	3	44	19	21	13	Day
Fawn buck	20	42	23	3	12	0	64	12	24	0	18	40	13	11	18	17	45	18	6	14	Night
	1	46	30	5	18	1	55	14	30	0	10	44	10	20	16	1	52	22	10	15	Day
Fawn doe	32	27	19	18	4	0	44	17	17	22	23	58	0	0	19	39	33	10	12	6	Night
	6	46	19	26	3	2	36	19	4	39	17	68	0	0	15	6	37	24	23	10	Day

[a]Vegetation types: D represents developed areas, P pine woods, B buttonwood zones, H hardwood areas, and M dense mangrove.

[b]Numbers are percent utilization of each vegetation type per quarter.

Table 15. Comparison of tooth row lengths of adult male and adult female Key deer, *Odocoileus virginianus clavium*, with other subspecies of white-tailed deer.

Subspecies	N	Range Length of upper cheek tooth row	N	Range Length of lower cheek tooth row	Source
O. v. borealis	30	84.7 - 76.3	27	90.2 - 76.2	Present study
O. v. borealis	96	85 - 60	95	92 - 71	Phillips (1920)
O. v. borealis	4	81 - 73	4	89 - 77	Barbour and Allen (1922)
O. v. osceola	3	77 - 72	3	83 - 78	Barbour and Allen (1922)
O. v. osceola	4	77.1 - 72.4	--	---------	Dickson (1955)
O. v. virginianus	5	81 - 76	5	88 - 81	Barbour and Allen (1922)
O. v. clavium	27	66.3 - 59.9	22	71.9 - 63.7	Present study
O. v. clavium	5	65.3 - 60.3	--	-----------	Dickson (1955)
O. v. clavium	2	67 - 62	2	73 - 70	Barbour and Allen (1922)

Table 16. Mean osmolality and equivalent percent NaCl of water samples collected from various keys during the period Jan., 1970 - June, 1971.

Collection Site	N	Osmolality (mOsm/Kg) $\bar{X} \pm$ S.E.	Range	Equivalent % NaCl
Big Pine Key	109	364±35	7-1514	1.08
Little Pine Key	16	401±122	13-1890	1.19
Big Torch Key	19	833±121	28-1504	2.50
Middle Torch Key	8	477±139	99-1077	1.42
Big Johnson Key	15	905±170	92-2196	2.72
Little Johnson Key	3	425±70	298-540	1.26
Water Key[a]	11	244±67	13-643	0.71
Howe Key	4	141±50	35-245	0.40
Cudjoe Key	5	548±274	112-1536	1.64
Horseshoe Key	1	794		2.38
Raccoon Key	1	521		1.55

[a]Does not correspond to usage of Dickson (1955:21). This is the largest island directly north of Big Torch Key.

Table 17. Precipitation, actual and percent of normal, recorded at Key West, Florida from January, 1968 to June, 1972.[a]

Month and Quarter	Precipitation (cm)						Percent of Normal				
	Normal[b]	1968	1969	1970	1971	1972	1968	1969	1970	1971	1972
January	3.9	0.2	9.8	20.9	1.0	7.0	5	251	536	26	179
February	5.0	8.8	3.4	5.3	7.0	5.3	176	68	106	140	106
March	4.5	11.1	2.2	5.6	T	1.5	247	49	124	0	33
Qtr 1	13.4	20.1	15.4	31.8	8.0	13.8	150	115	237	60	103
April	6.3	0.6	7.9	0.3	0.6	1.9	10	125	5	10	30
May	7.0	20.3	7.7	6.7	11.1	6.7	290	110	96	159	96
June	10.1	23.8	25.3	5.0	7.0	36.7	236	250	50	69	363
Qtr 2	23.4	44.7	40.9	12.0	18.7	45.3	191	175	51	80	194
July	10.5	9.7	10.6	29.7	12.2	--	92	101	283	116	-
August	11.0	12.1	5.7	10.2	22.9	--	110	52	93	208	-
September	17.1	17.5	25.9	13.6	13.9	--	102	151	80	81	-
Qtr 3	38.6	39.3	42.2	53.5	49.0	--	102	109	138	127	-
October	14.8	17.3	54.8	20.4	28.2	--	117	370	138	191	-

Table 17. Continued.

Month and Quarter	Precipitation (cm)						Percent of Normal				
	Normal[b]	1968	1969	1970	1971	1972	1968	1969	1970	1971	1972
November	7.1	10.0	4.6	0.4	4.3	--	141	65	6	61	-
December	4.3	0.5	2.0	0.9	4.0	--	12	47	21	93	-
Qtr 4	26.2	27.8	61.4	21.7	36.5	--	106	234	83	139	-

[a]Data from U.S. Dept. Commerce, Climatological Data, Vol. 19-22.

[b]Normal values are based on long-term average as of 1969.

Table 18. Census estimates pertinent to the herd composition during April-June, 1969 and figures utilized in considering potential rate of increase during 1969-1972.

Item	Schumacher-Eschmeyer Estimates		Revised Numbers	Adults by Age			
	April-June 1969	Oct. 1968-Sept. 1969		2	3	4	5
Total deer	70 ± 12.9	61 ± 5.6	70	-	-	-	-
Adult female	29 ± 5.5	26 ± 3.6	36	12	15	3	6
Adult male	7 ± 1.6	9 ± 1.8	12	6	3	2	1
Yearling female	14 ± 19.8	9 ± 3.2	12				
Yearling male	8 ± 1.0	7 ± 0.8	10				

Table 19. Number of adult and yearling deer at annual intervals beginning in April-June, 1969 as measured by road censuses and calculated by method discussed in text.

Type of Estimate	1969	1970		1971		1972	
	Deer	Deer	Increase	Deer	Increase	Deer	Increase
Census	70	98	28[a]	117	47	96	26
Calculated	70	81	11	94	24	105	35

[a]Increase column always refers to increase above numbers in 1969.

FIGURES

Figure 1. Outline map of Big Pine Key showing roads traversed during the 10-mile census.

Figure 2. Outline map of Big Pine Key showing roads traversed during the sunrise and sunset censuses.

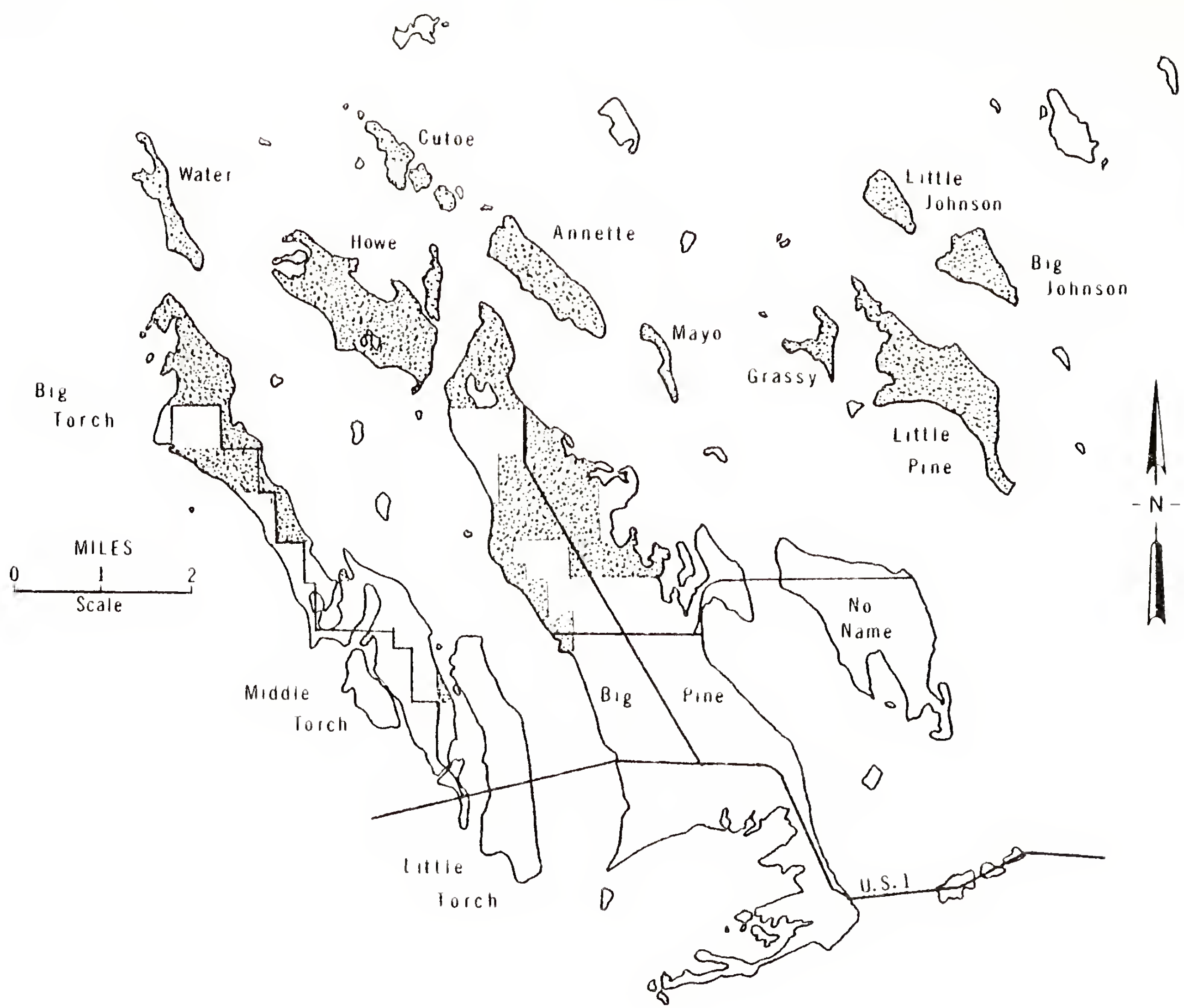

Figure 3. Map of the easternmost islands of the lower Florida Keys within the Key deer range. Shaded area represents Refuge lands incorporating island complexes inhabited by deer. Management proposals are limited to these islands.

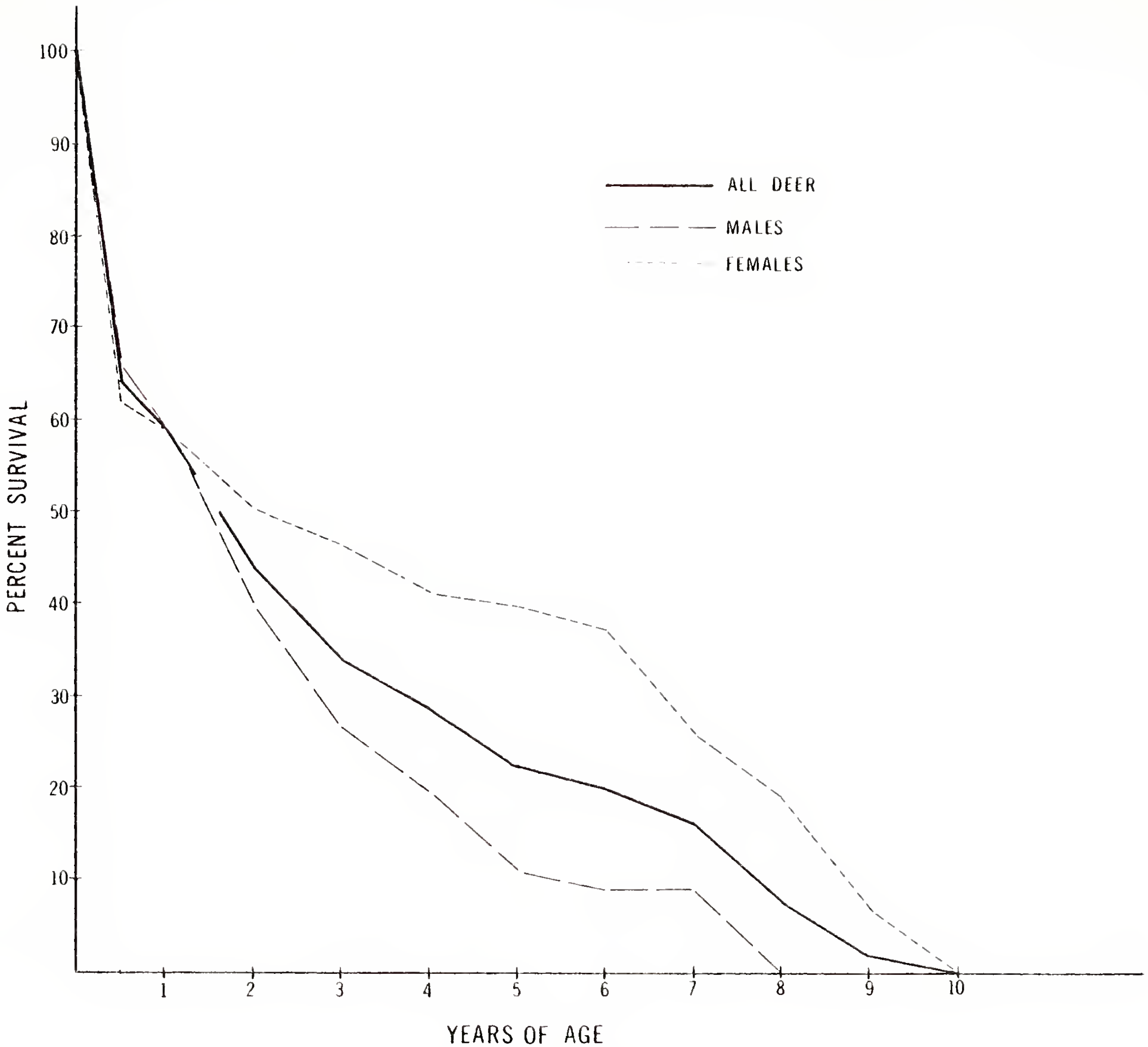

Figure 4. Survivorship curve for the Key deer population based on the percent of marked deer in each age class that survived to the next age class. Determinations were based on deer marked during January, 1968 through June, 1973.

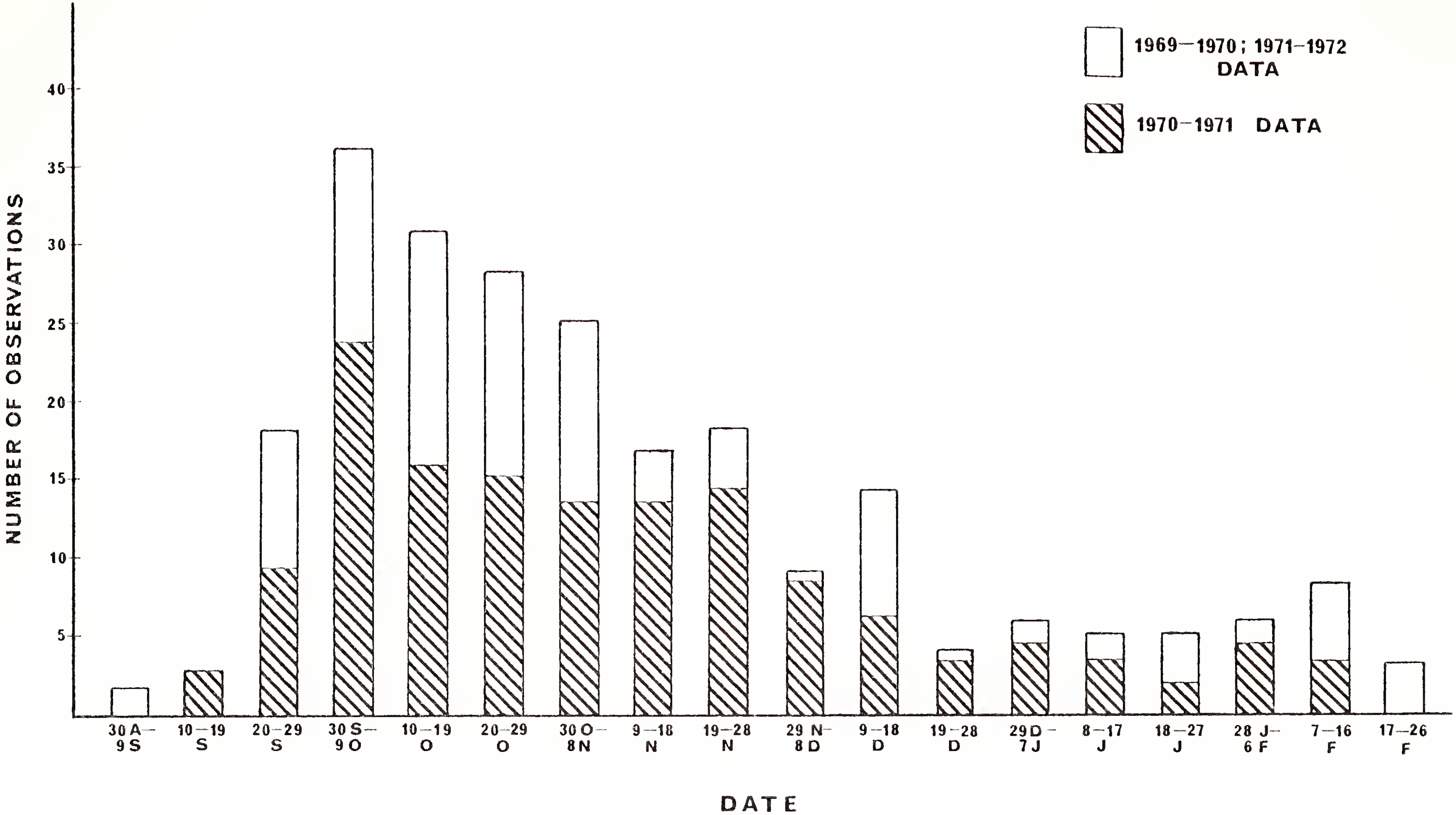

Figure 5. Observations of breeding activities. Each column represents the number of breeding observations recorded during that time period. Shaded area represents 1970-71 breeding season during which observations were made throughout the reproductive season. Data for 1969-70 and 1971-72 were not for the entire periods.

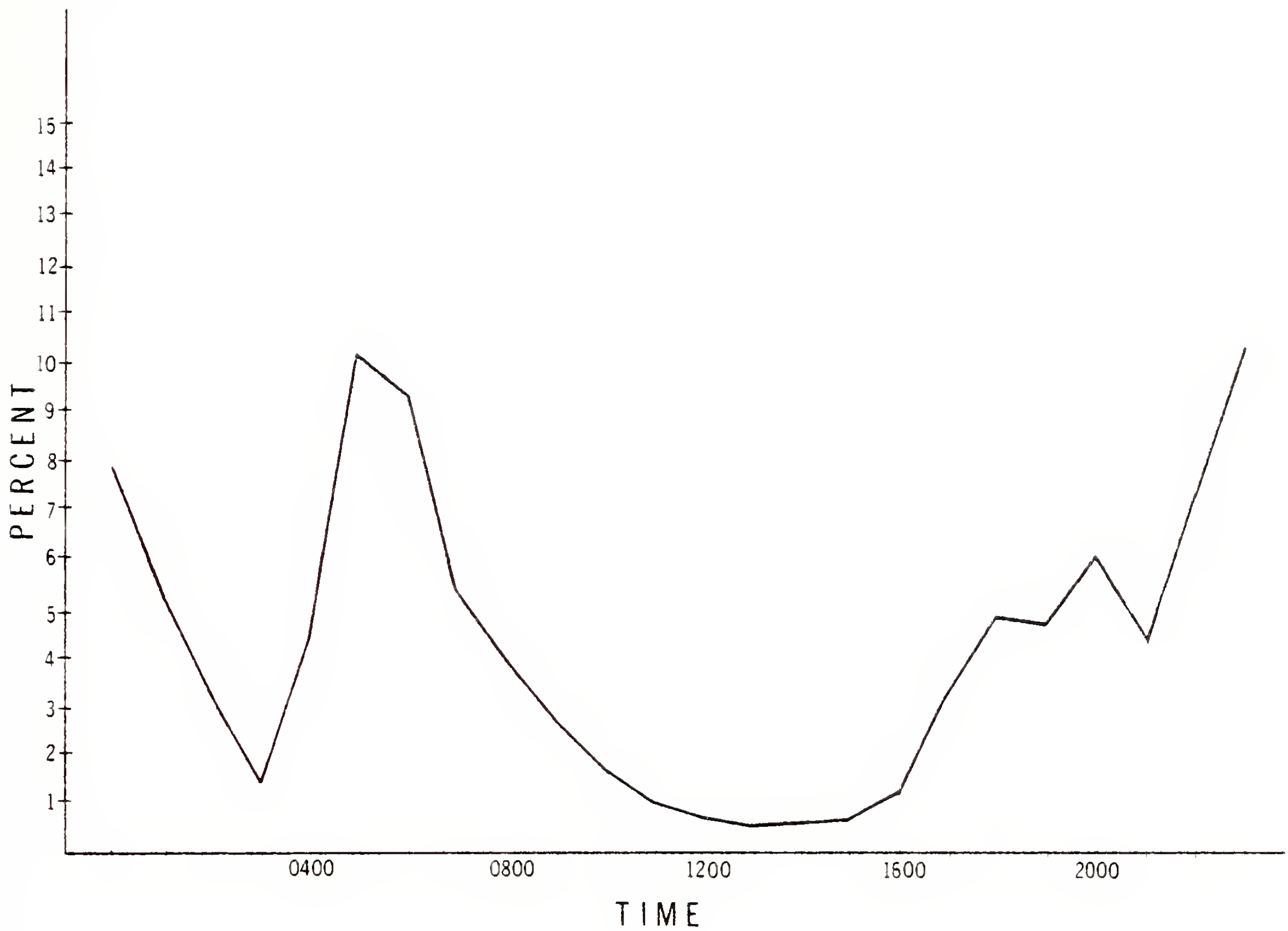

Figure 6. Times when deer were seen in open areas. The percent of all observations in the open are correlated with the times when they occurred.

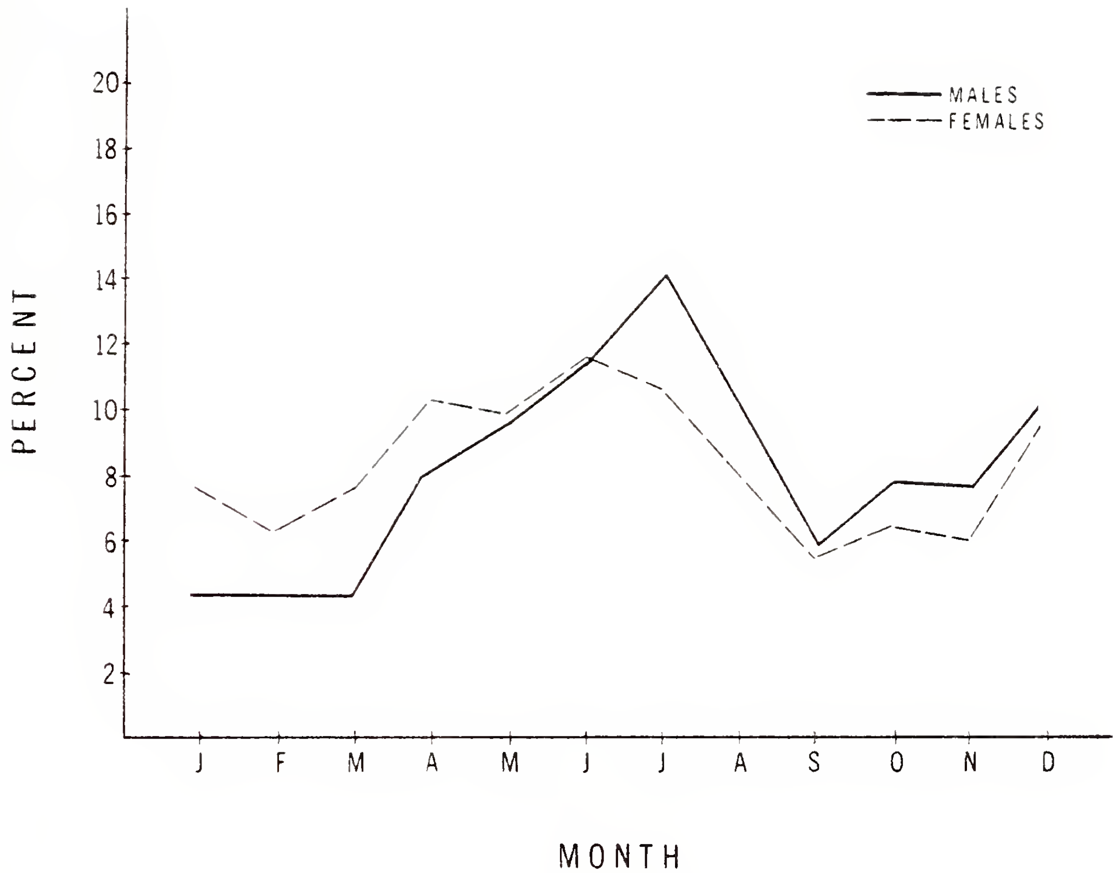

Figure 7. Monthly variations in use of open areas and roadsides. The percent of all observations in open areas are plotted against their respective times of occurrence for males and females.

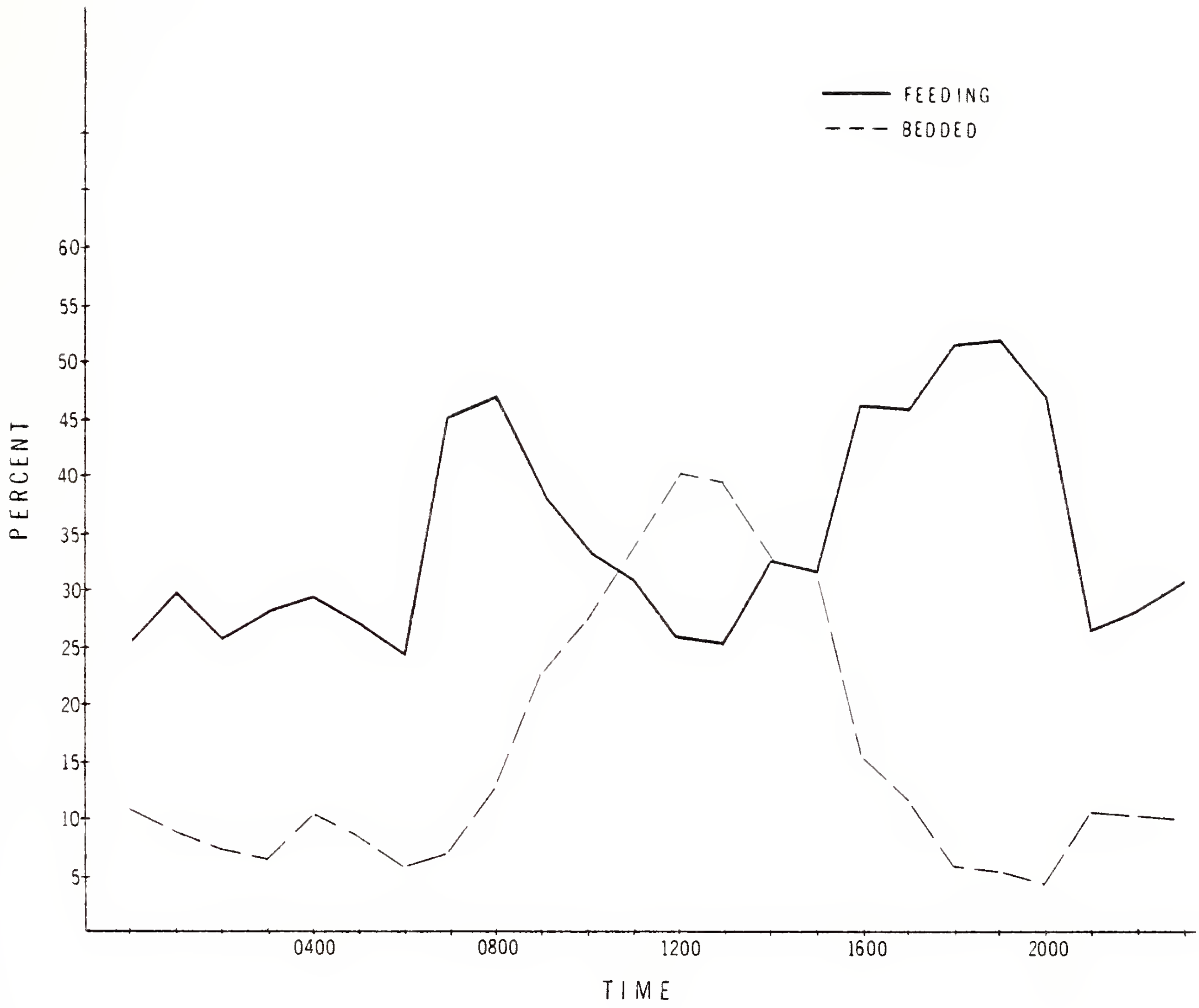

Figure 8. Observations of Key deer bedding and feeding activities. The percentage of the time that deer were seen to be bedded and feeding are correlated with the times of occurrence.

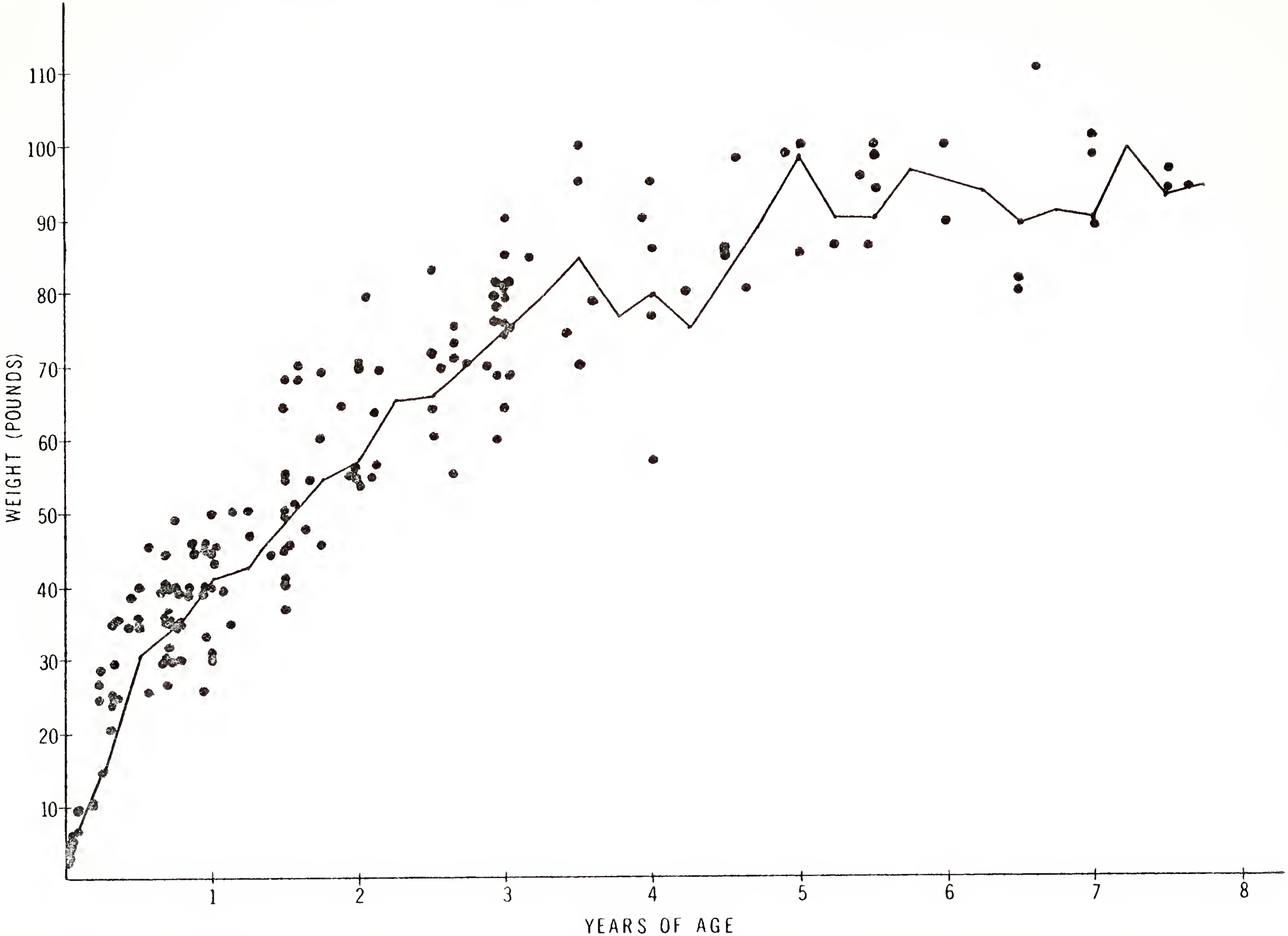

Figure 9. Body weights of male Key deer captured during the study. Ages were estimated based on tooth eruption and wear. The mean weights for each age class are indicated by the line.

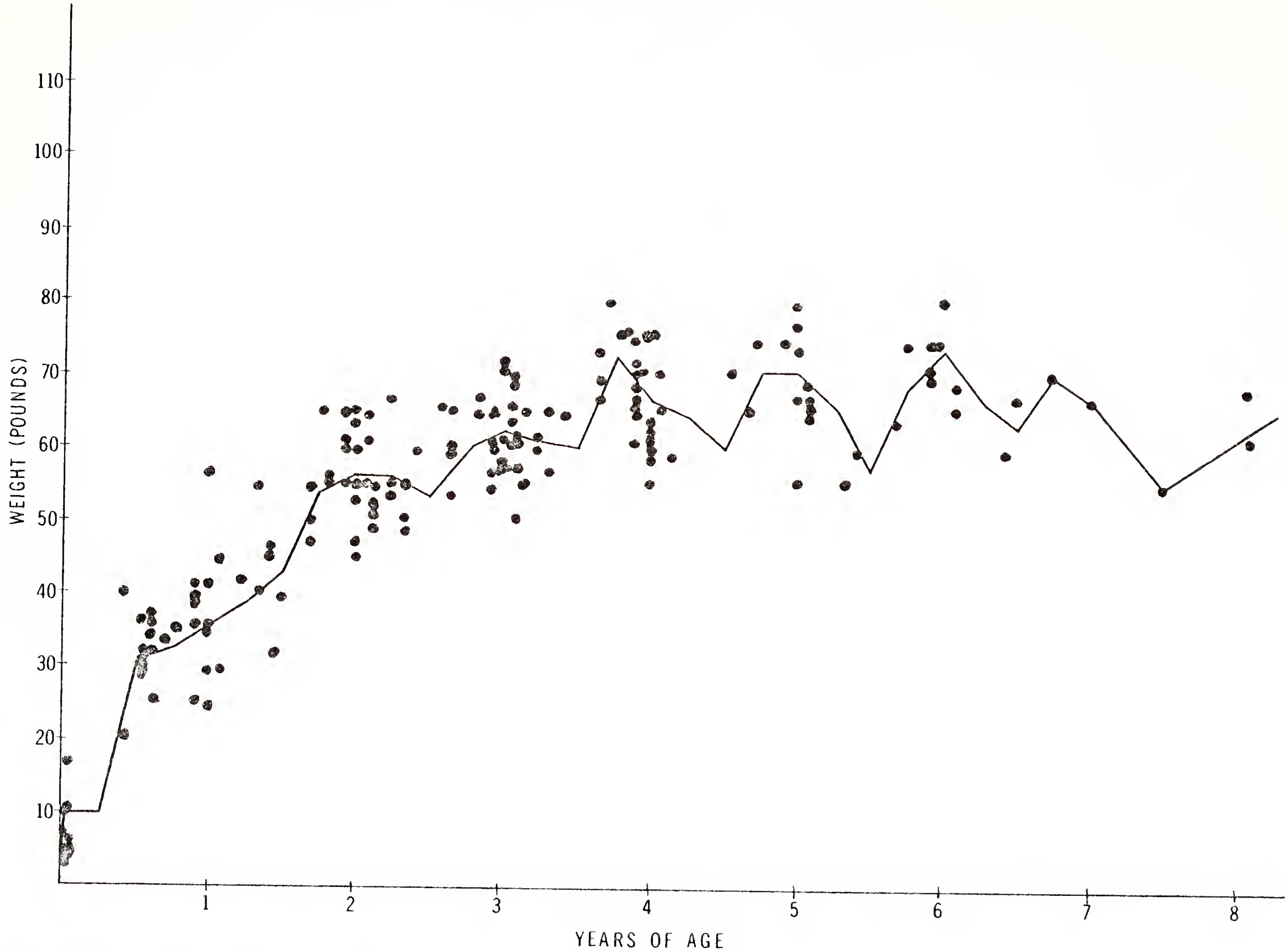

Figure 10. Body weights of female Key deer captured during the study. Ages were estimated based on tooth eruption and wear. The mean weights for each age class are indicated by the line.

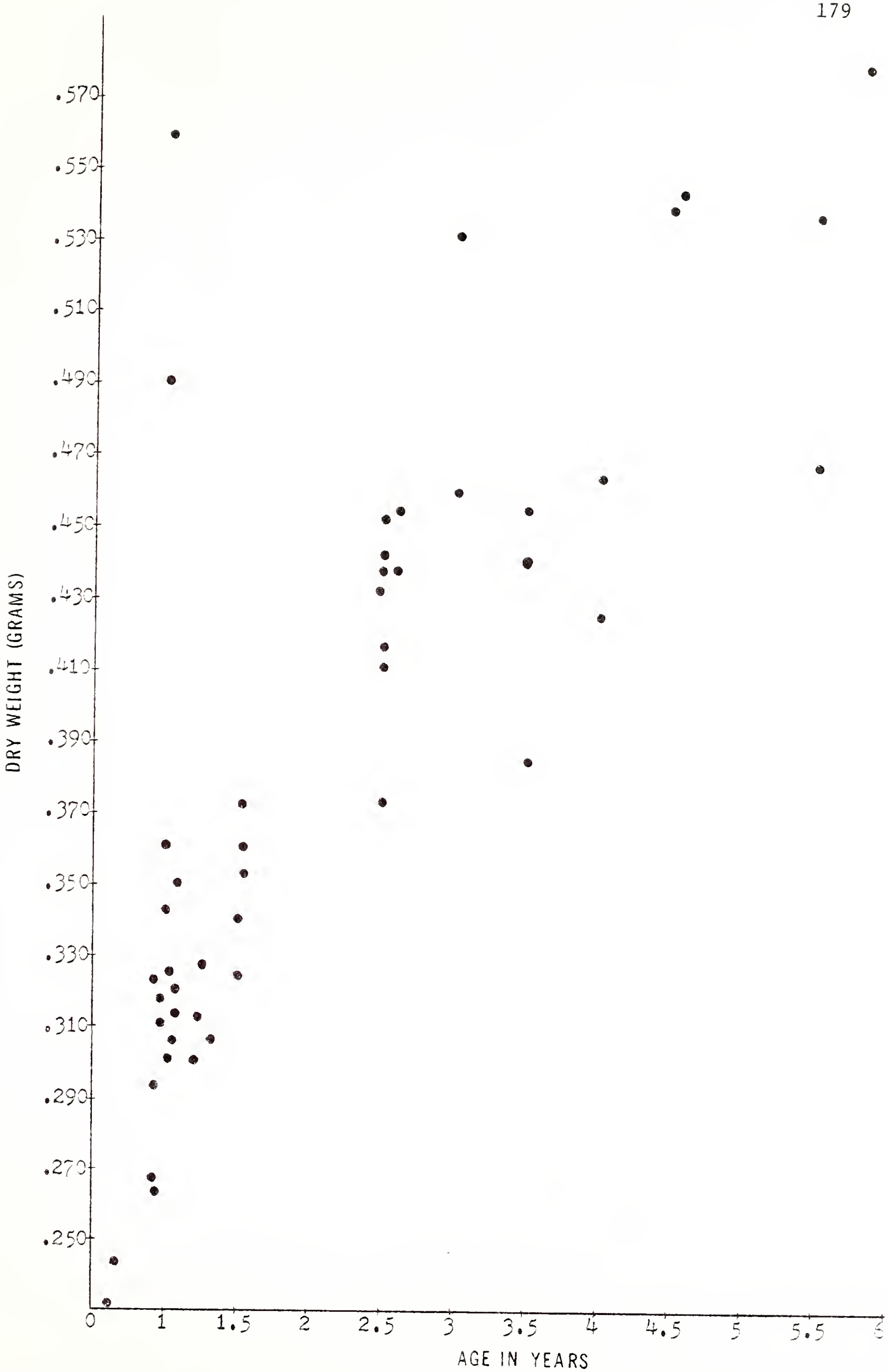

Figure 11. Dry weights of Key deer eye lenses correlated with age at time of death as determined by tooth wear.

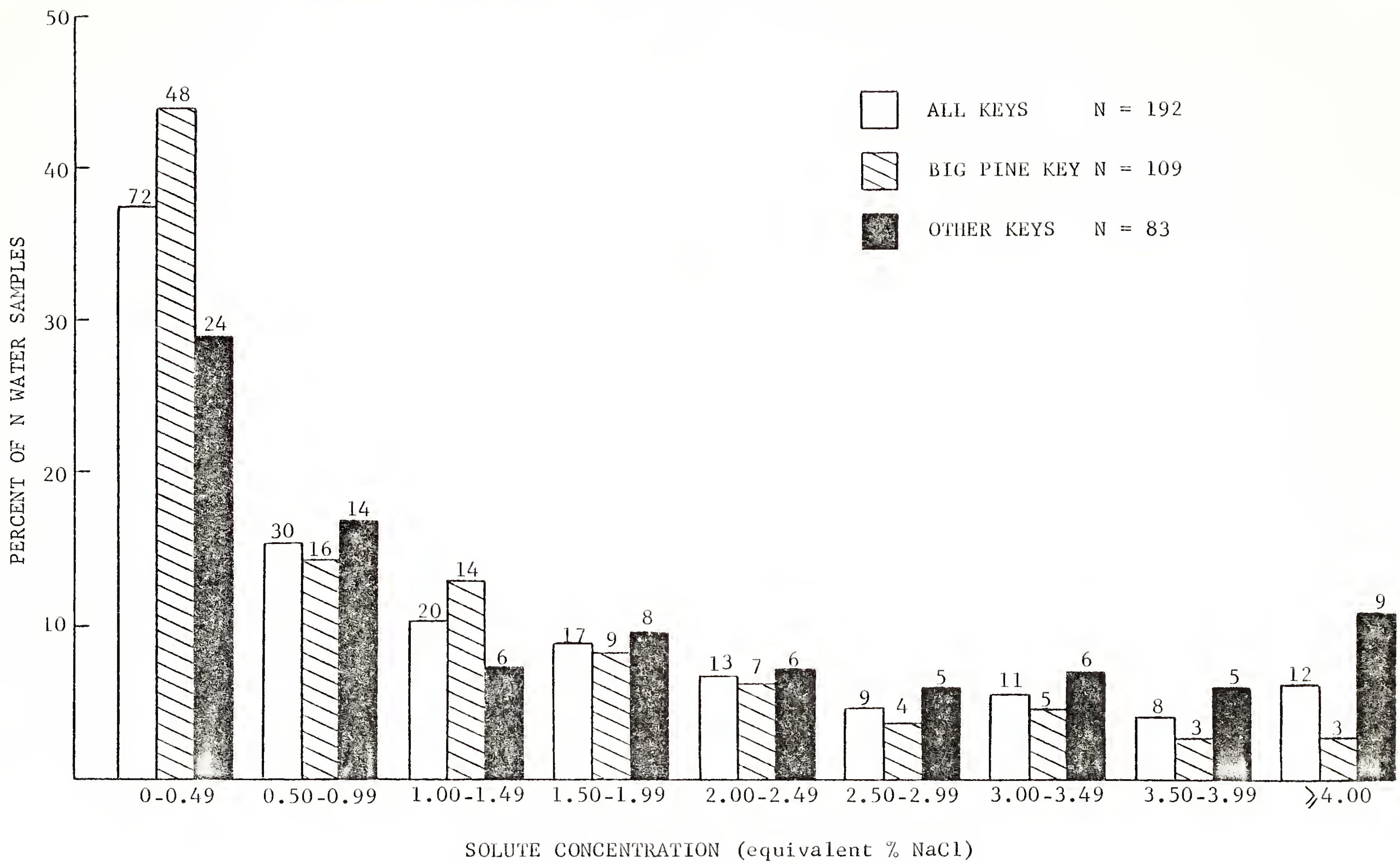

Figure 12. Percentage distribution according to solute concentration of water samples collected from potential Key deer watering sites on Big Pine, Little Pine, Big Johnson, Little Johnson, Big Torch, Middle Torch, Horseshoe, Raccoon, Water, Howe, and Cudjoe keys during time period Jan., 1970 - June, 1971. Numbers above each bar indicate the sample size in each category.

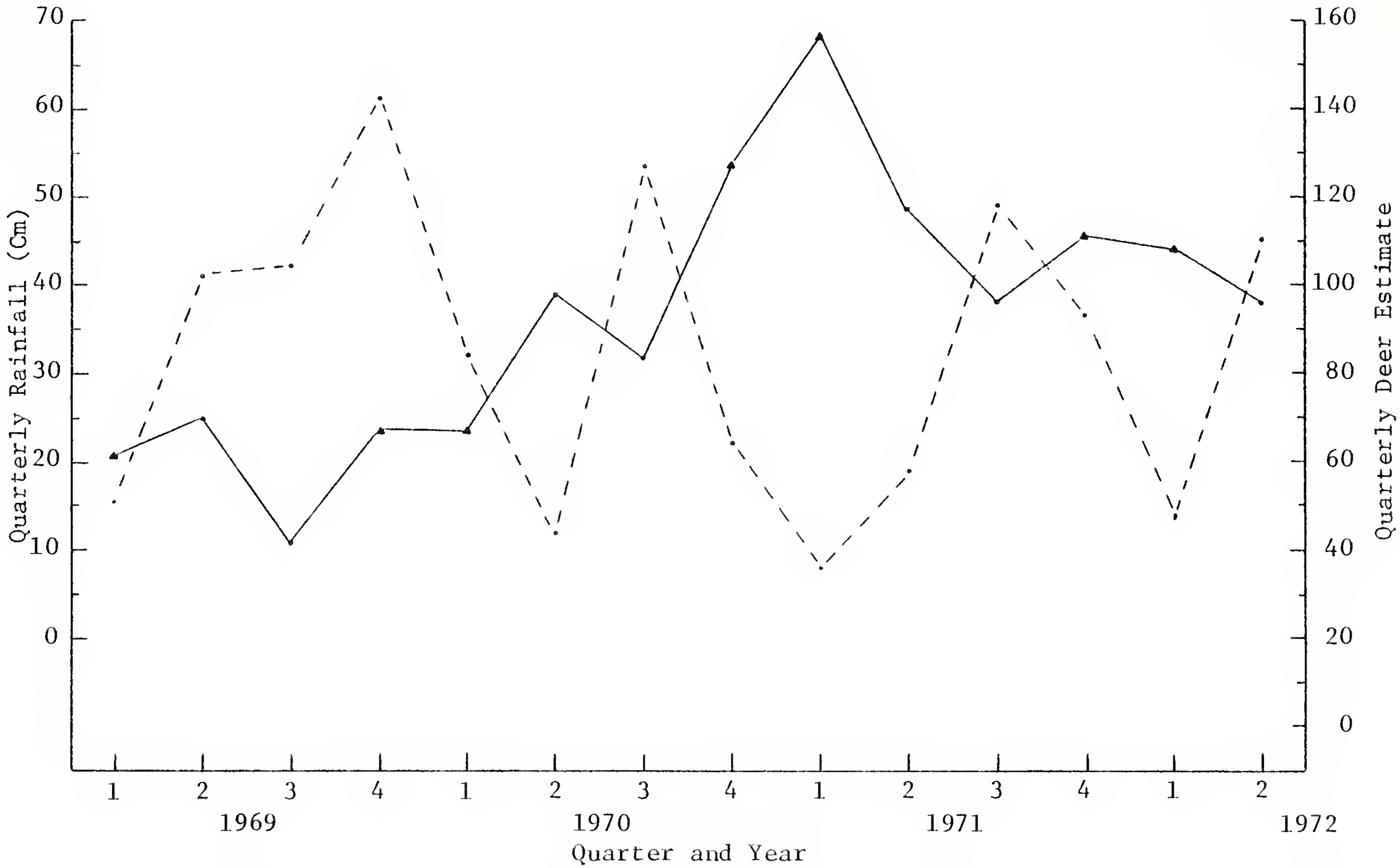

Figure 13. Quarterly rainfall at Key West, Florida (dotted line) and Schumacher-Eschmeyer population estimates for portion of Big Pine Key covered by a weekly 10-mile road census (solid line). Quarter 1 represents period of Jan.-March, inclusive. Triangles indicate estimates which include fawns, others include only adults and yearlings.

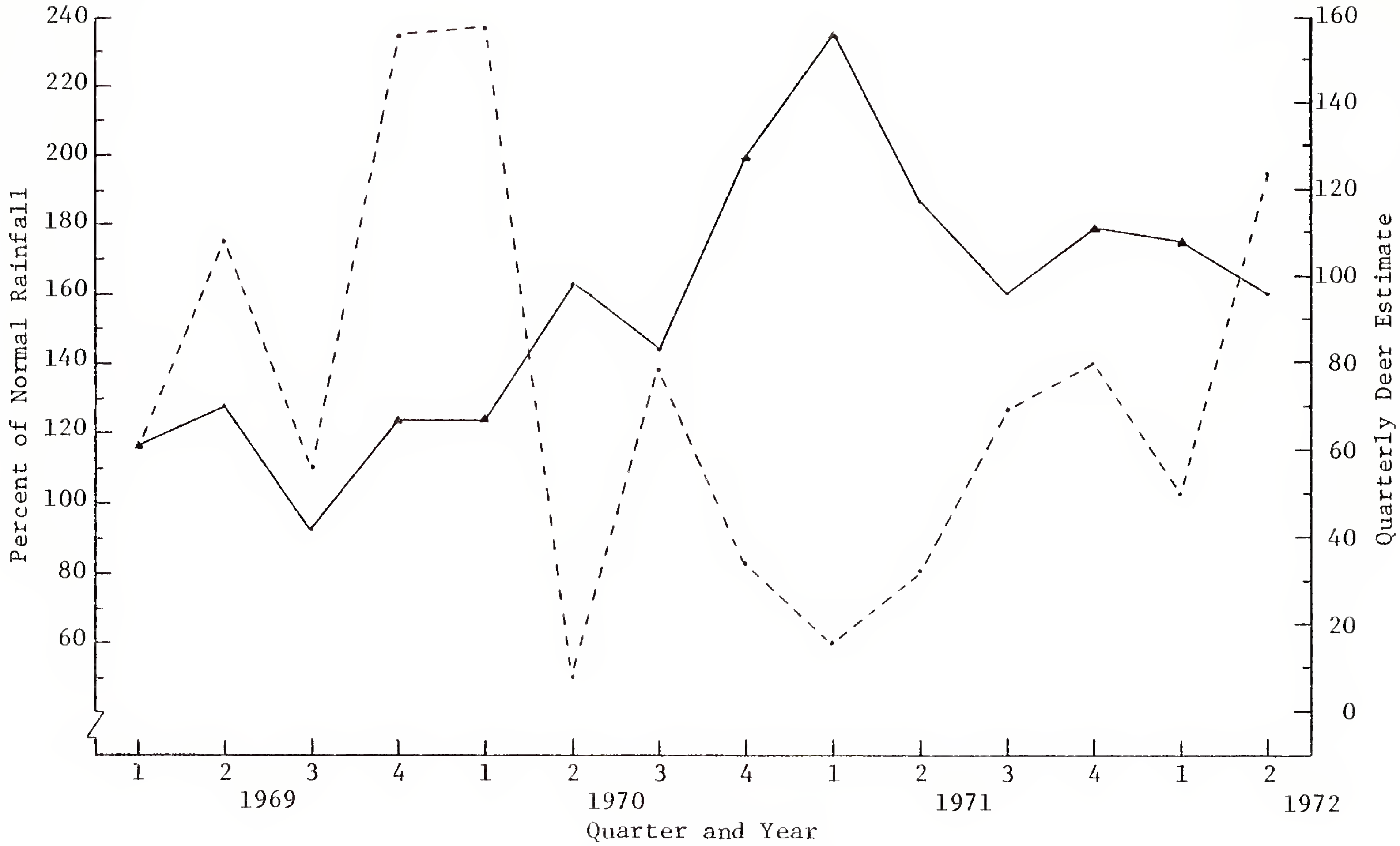

Figure 14. Percent of normal quarterly rainfall at Key West, Florida (dotted line) and Schumacher-Eschmeyer population estimates for portion of Big Pine Key covered by a weekly 10-mile road census (solid line). Quarter 1 represents period of Jan.-March, inclusive. Triangles indicate estimates which include fawns, others include only adults and yearlings.

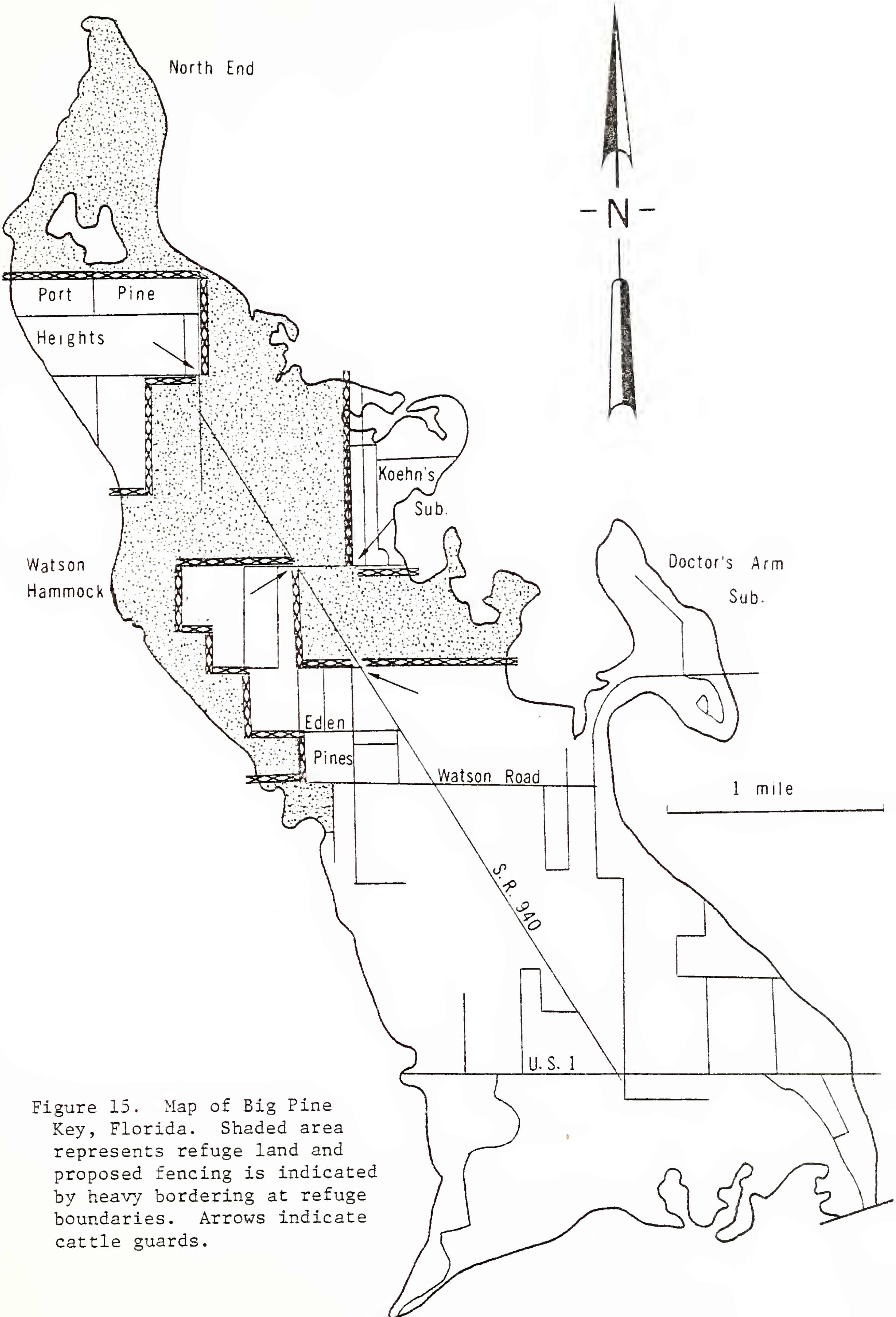

Figure 15. Map of Big Pine Key, Florida. Shaded area represents refuge land and proposed fencing is indicated by heavy bordering at refuge boundaries. Arrows indicate cattle guards.

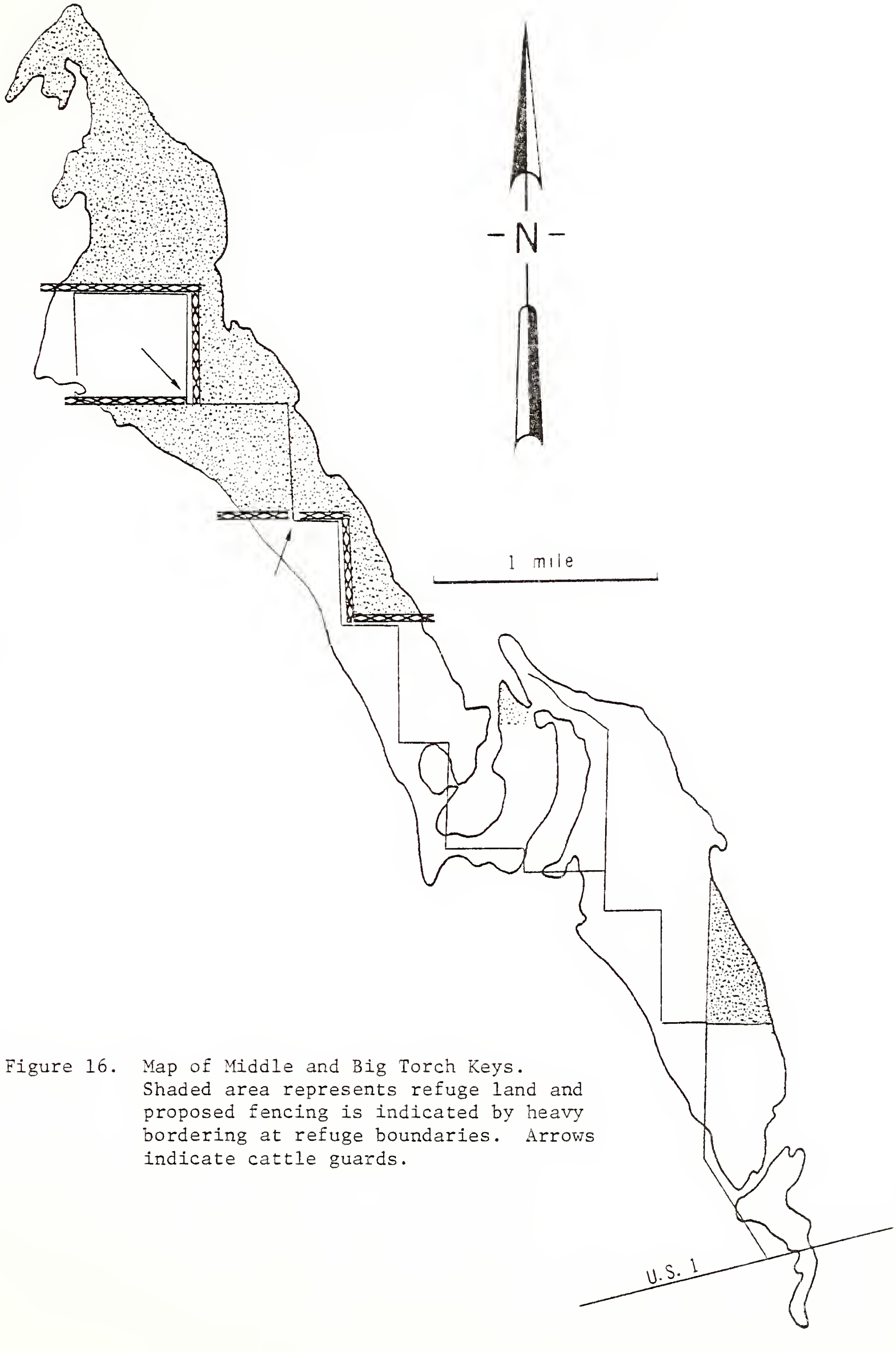

Figure 16. Map of Middle and Big Torch Keys. Shaded area represents refuge land and proposed fencing is indicated by heavy bordering at refuge boundaries. Arrows indicate cattle guards.